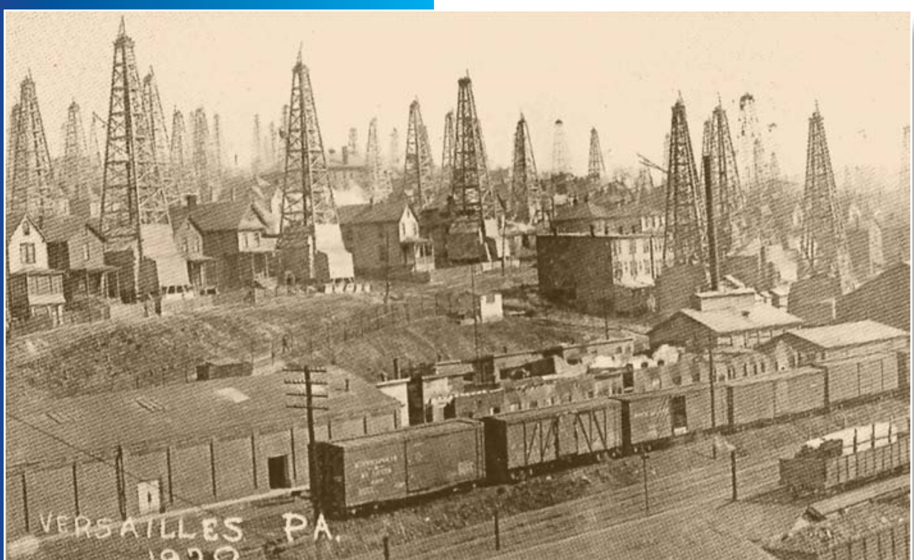
# Methane Emissions Project

## Borough of Versailles, Pennsylvania




# FINAL REPORT

**October 31, 2007**

*Prepared by*

National Energy Technology Laboratory

# DISCLAIMER

## ACKNOWLEDGEMENTS

The National Energy Technology Laboratory (NETL) would like to acknowledge and thank the Borough of Versailles council for their assistance and support of this project and, in particular, the following council members who directly provided support and effort to facilitate its completion: Walt Winkler, Council President; Linda Sheedy; Anita Gricar; William Larson; Robert Stanesic; Amy Barnes; and Patricia Brown. NETL would also like to thank Police Chief William Kruczek, Linda Salzmann in the Borough office, and Bill Buzalka and Tom Kopchinski with the Borough Street Department for their assistance in the day-to-day needs in completing this project. NETL appreciates the technical advice and support to this project provided by personnel from the Pennsylvania Department of Environmental Protection, Oil and Gas Division. Thanks are also given to the citizens of Versailles Borough for providing historical data and their patience and cooperation throughout the duration of this project.

Cover Photo: Versailles, PA, circa 1920 (Photo courtesy of Mrs. Josephine Cindric).

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# 1.0 Background

Versailles is a Borough located in southwestern Pennsylvania, in Allegheny County, and southeast of the city of Pittsburgh (Figure 1). It is bordered to the north and east by the City of McKeesport and to the south and west by the Youghiogheny River. The 2000 census reported the population of Versailles as 1724. Since the 1960's, the Borough has had problems with stray hydrocarbon gas leaking from abandoned and improperly plugged gas wells. As a result, some residents have been forced to leave their homes or businesses until the stray gas problem entering their structures was eliminated; sometimes the structures were condemned as uninhabitable.

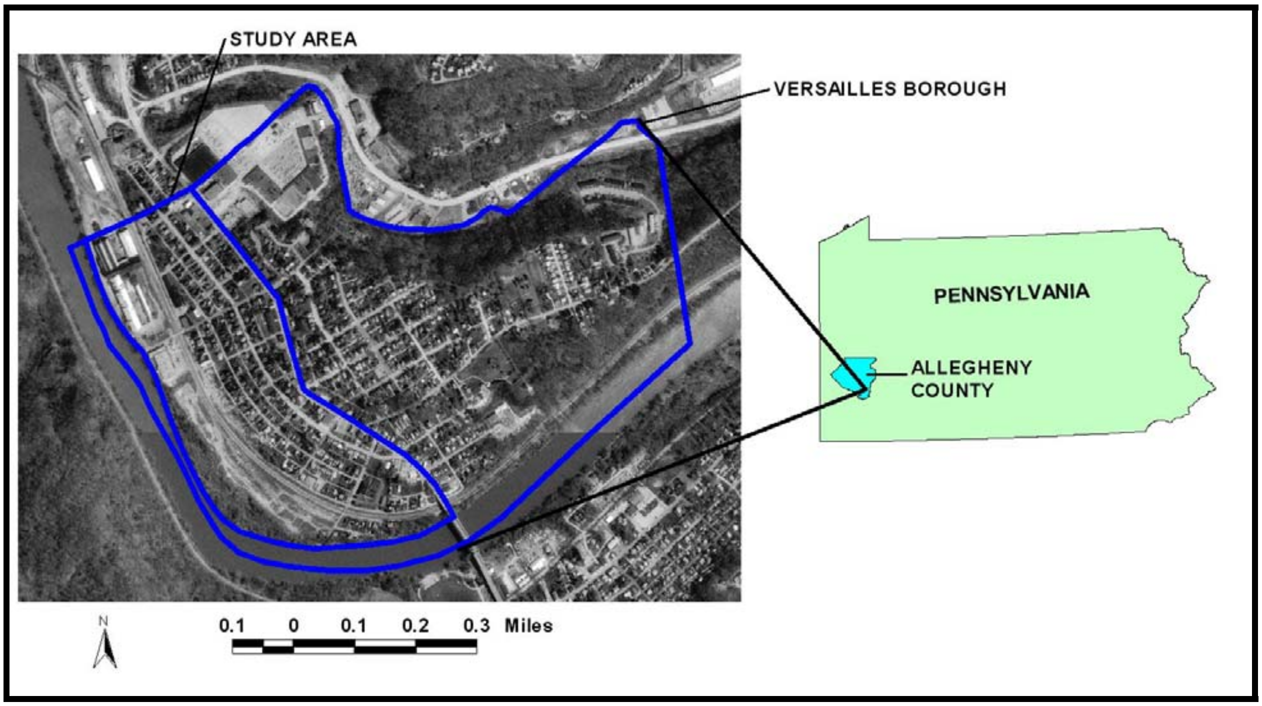


**Figure 1.** Location map of Versailles, Pennsylvania.

The underlying cause of the problem is that during the period from 1919 through 1921, over 600 wells were drilled as part of the McKeesport Gas Field (Plate 1). The primary target reservoir was the Speechley sandstone at a depth of approximately 3,000 feet, although a few wells were drilled into the overlying Elizabeth and Murrysville sandstones at the southern end of the Borough near the Boston Bridge. The big gas boom of the time saw interests in wells being bought and sold on the street corners of Versailles Borough and neighbor pitted against neighbor as each tried to be the first to get the gas underlying their property. As a result, over 175 wells were drilled in the Borough of Versailles. A majority of these wells were drilled between Walnut Street and the Youghiogheny River, where landowners lived on 25- by 100-foot lots, as shown in Figure 2. Each landowner wanted a well to ensure that they, rather than their neighbors, received the value of the gas from below their property. Above Walnut Street, the land was primarily rural, with landowners holding multiple acre plots of land. Here, fewer wells were drilled with larger well spacing to produce the underlying gas. Many of these wells were outside the productive area of the Speechley sandstone.

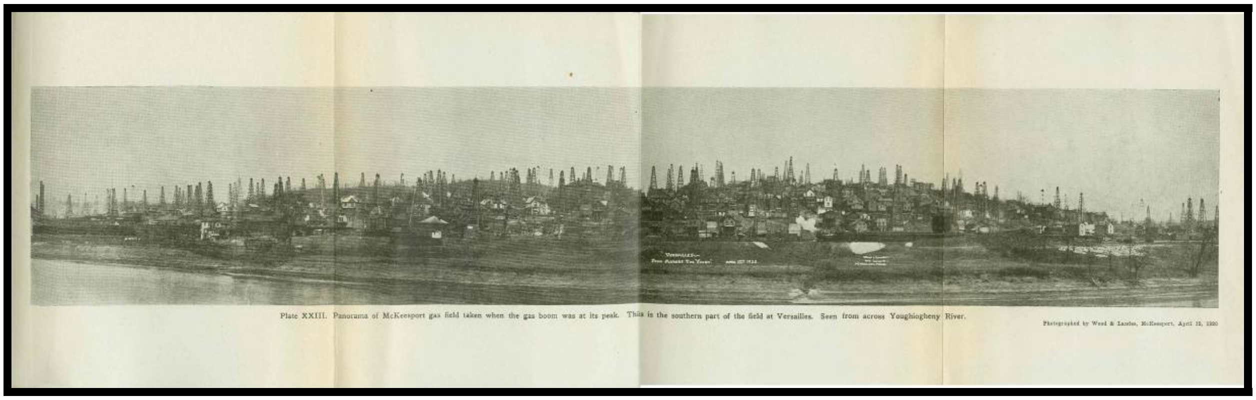


**Figure 2.** View of Versailles from across the Youghiogheny River during the peak drilling period (from M. E. Johnson, 1929).

Of the 175 or more wells drilled in the Borough of Versailles, some were non-producing and were abandoned without placing casing in the wells. Others produced for only a few years as over-drilling and over-production rapidly depleted the reservoir. These wells were cased, but were left abandoned and unplugged after production ceased. The call for steel as part of the war effort during World War II caused a renewed interest in the Versailles Borough wells – not in production, but in removing an unknown number of abandoned steel casings and wellheads (valves and piping associated with the well above ground level). Again the wells were left abandoned and unsealed, but this time there were fewer casings or wellheads remaining to mark the wells on the surface. This left three types of abandoned wells in Versailles Borough – wells without any casing, wells with only the surface conductor casing left (which they were unable to pull from the ground), and wells with the surface conductor and some of the original production casing. These three types of wells are shown graphically in Figure 3. Construction boomed after the war as soldiers returned to work and start families. Homes and businesses were built adjacent to or over the now uncased and open wells. Over time, gas has migrated up the old, uncased wellbores from multiple gas-bearing sources, including conventional gas reservoirs and coal seams, charging the shallower formations or using these shallower formations as lateral migration pathways. Somewhat at the same time as the natural gas drilling activities, mining of the Upper Freeport coal began in the Hubbard deep mine, located north and east of the Borough (Figure 4). Mining occurred from the early 1920’s to the early 1960’s. The Upper Freeport coal seam is known to be very gassy and explosions occurred in the mine during operation. Finally, further complicating things is apparent gas storage fields underground which, based on limited information, involved the injection of natural gas into an intermediate reservoir lying between the Speechley sandstone and the coal seam, and potentially beneath Versailles, in the late 1950’s.

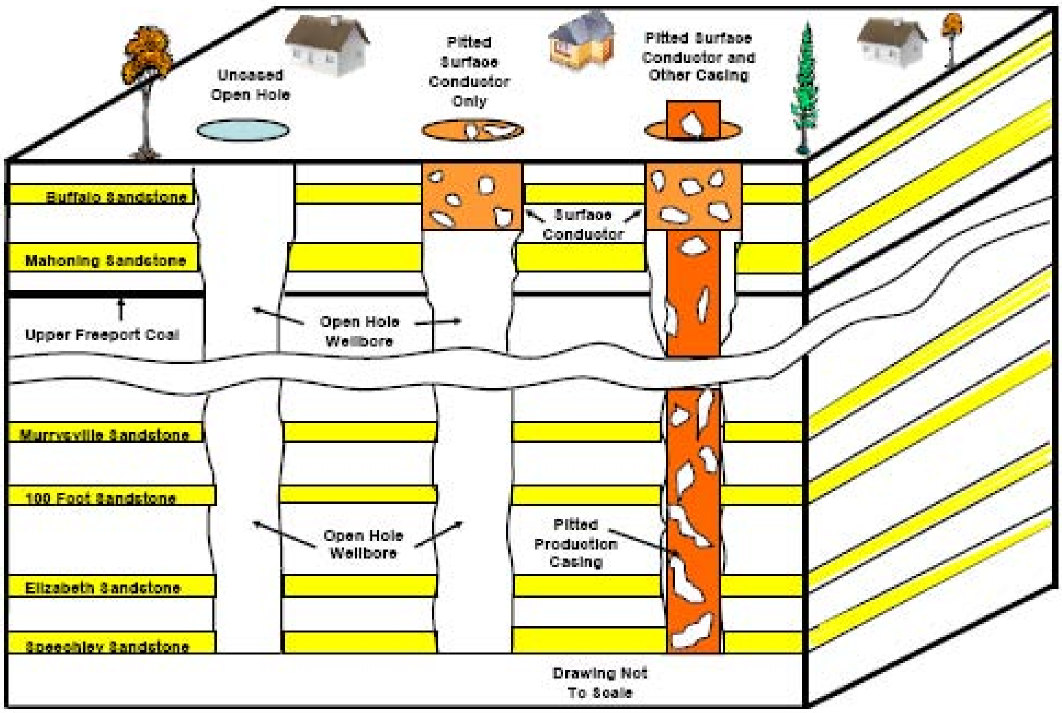


**Figure 3.** Three typical types of abandoned wells found in Versailles Borough and key geologic formations.

The first reported presence of hydrocarbon gas leaking into structures in Versailles was in 1963 near the original coal mine opening. The Murrysville anticline (a slight arch in the subsurface formations) underlies Versailles, creating a place for the gas to accumulate near the anticline's crest (Figure 5). Over time, gas has migrated from the deeper more conventional gas reservoirs via the old abandoned gas wells, resulting in an accumulation of gas near the crest and along the flanks of the anticline. Previous investigations were limited to surface findings and installation of methane removal vents, and did not delve into the possible subsurface source or sources of the problem. Over time, some of the early methane vents have been removed or deteriorated to the point of ineffectiveness.

In 2005, U.S. Representative Mike Doyle, Democrat, Pennsylvania's 14th District, secured federal funding for a study to determine how to potentially eliminate the threat to public safety presented by stray natural gas leakage in the Borough of Versailles. Because of its expertise in geoscience, the U.S. Department of Energy's National Energy Technology Laboratory (NETL) was given the task of managing an investigation into the problem. The objective of the study was to develop a set of potential remediation options. NETL has neither the legal authority nor the capacity to conduct remediation efforts. In order to develop a set of remediation options, it was necessary to: (1**)** define the extent of the problem, (2) better understand the physical and geological setting, (3) determine the source(s) of natural gas leakage, (4) evaluate potential migration pathways, and (5) locate old gas wells within the Borough, methane gas sources, migration pathways, existence of buried wells, and potential remediation actions. NETL collaborated with Research and Development Solutions (RDS, the NETL technical support contractor), the University of Pittsburgh, the Pennsylvania Department of Environmental Protection (PA DEP), private industry, and local government officials. More detailed technical data are provided in two accompanying reports, shown as attachments, from the two primary contractors. Attachment I covers work completed by RDS in the areas of field investigations, analysis of vented gas, results of opening two old wells, and possible remediation alternatives. Also included is a section covering work conducted by Department of Energy (DOE) personnel, with the assistance of RDS personnel, on locating subsurface abandoned gas wells using magnetic surveys and a highly sensitive methane gas detector. Attachment II covers subsurface and marine seismic investigations completed by University of Pittsburgh personnel.

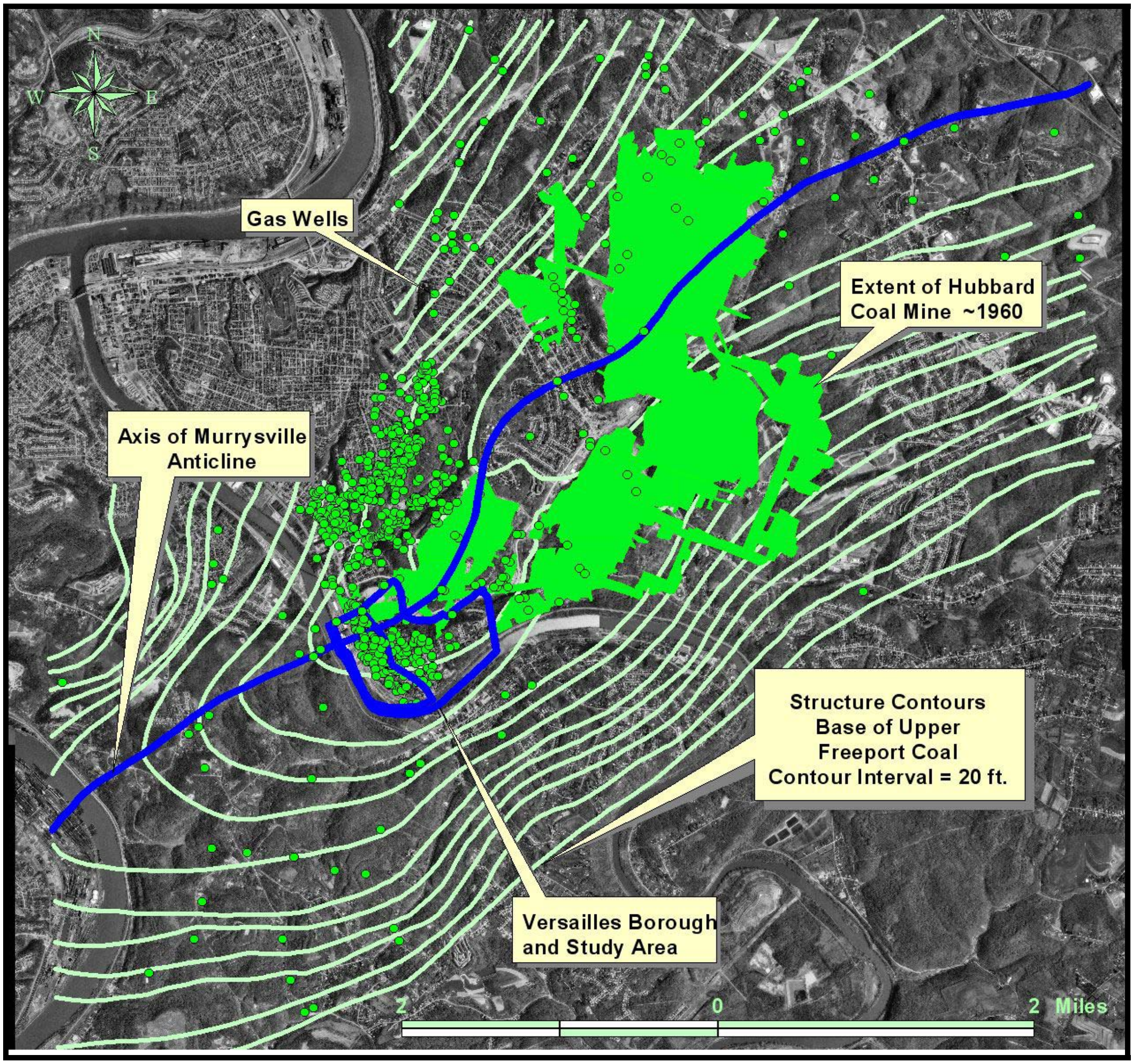


**Figure 4.** Relationship of the Hubbard Mine to the Murrysville Anticline, and structural contours on the base of the Upper Freeport coal seam, indicating the anticlinal structure of Versailles and the study area. The small circles are locations of old gas wells.

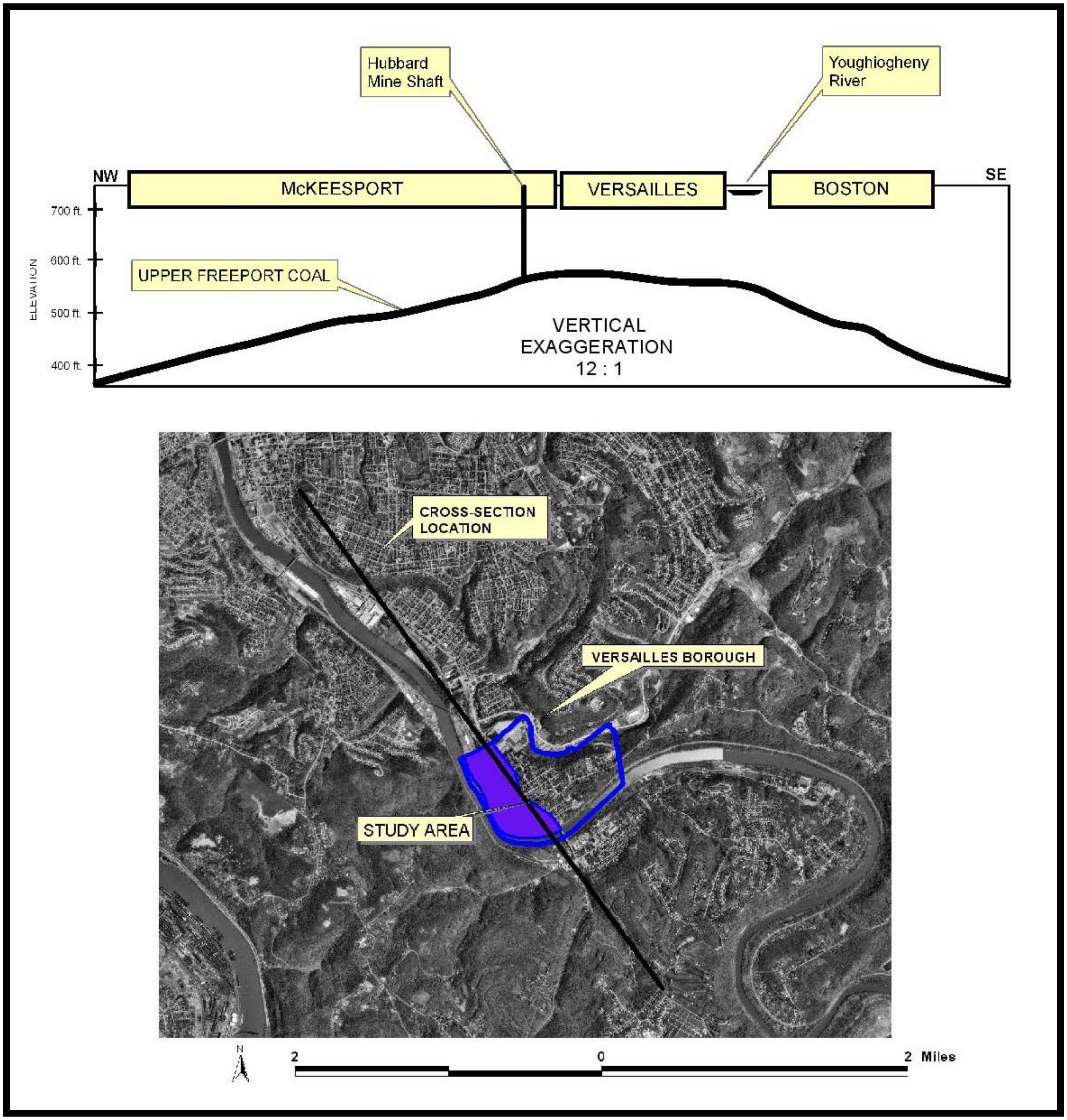


**Figure 5.** Cross-section of the Upper Freeport coal, showing the relationship of the Hubbard Mine portal, the study area, and Versailles Borough to the Murrysville anticline.

The objective of the study was to develop a set of potential remediation options. To do this, it was necessary to understand the physical and geological setting, determine the source(s) of natural gas leakage, evaluate potential migration pathways, define the extent of the problem, and locate old gas wells within the Borough. Summarizing the results:

1) Based on input from the Borough Council and local residents, the project study area was defined and bounded by McKeesport to the north, Walnut Street to the east, Boston Bridge to the south, and the Youghiogheny River to the west. This area has seen the highest frequency of stray hydrocarbon gas occurrences in the Borough. However, one should not assume that this is the only area within the Borough having stray hydrocarbon gas problems.

2) Geologic structure in the area is controlled by the Murrysville Anticline, a gentle up-warp of the subsurface geologic formations, with a slight northwest – southeast trend in the area and plunges to the southeast. The crest of the anticline passes near the center of the Versailles Borough study area. Seismic surveys of both a portion of the Borough and the Youghiogheny River indicated no faulting or major fracturing within the study area. The seismic surveys also showed no major pockets of shallow or deep gas or potential commercial sources of natural gas.

3) No single source for the stray hydrocarbon gas was found in the Borough. Gas analyses of samples taken from the vents and wells in the Borough indicate that it is a mixture of natural hydrocarbon gas, mostly methane, and most of it apparently derived from Devonian Age formations, which could include the Speechley sandstone (the original target reservoir for early drilling activities) as well as all the conventional gas reservoirs stratigraphically located above the Speechley. Some natural gas was also apparently stored in one of these intermediate strata, and could possibly be contributing to the problem. Some gas may also be originating from the multiple coal seams in the area, including the Upper Freeport coal that was mined locally at the Hubbard Mine north and east of Versailles, though it is important to note that the study area was apparently not undermined. Finally, although there were reports of coke gas injected into subsurface strata in the past, there were no indications of this in the gas samples collected.

4) The abandoned and improperly plugged wellbores appear to be the primary vertical migration pathways for the stray hydrocarbon gas, usually producing a point-source of gas at the surface. However, not all old wells are vertical conduits for the deeper gas. Some wellbores are acquiring stray gas from lateral movement of the gas in shallower formations, which were apparently previously charged with methane that seeped upward from other wellbores. This was evident in two wells opened and video taped with a down-hole camera as part of this study. A video survey of the opened well on Walnut Street showed gas entry from a cleat in the Upper Freeport coal seam at a depth of 248 feet. In the well opened by the Borough garage, the gas appeared to be entering the wellbore from the Buffalo sandstone, which lies approximately 17 feet below the surface and extends to a depth of approximately 65 feet. The exact gas entry depth could not be determined within the sandstone unit due to suspended clays and coal fragments in the water obscuring the wellbore sides. There is no way of determining which wellbores are being sourced from deeper formations and which are being sourced by shallower formations without opening and cleaning all of the wellbores. Due to the location of the wells relative to existing structures, this would be impossible at some sites and very expensive at others; since it became clear that there were no pockets of gas that could be drained and vented, no additional effort was put into cleaning out old wells for this study.

5) Over the years, many of the old wellbores have lost their surface exposure due to construction, partial plugging by the landowner, or placement of fill over the well. As a result, it appears that during wet weather, the stray gas tends to migrate laterally through the overlying soil and shallow permeable geologic formations towards buildings. This lateral migration increases as the upper zones of the soil become saturated trapping the gas in the lower soil zones and permeable geologic formations. The same tendencies are present during periods of high barometric pressure, which also tend to suppress the vertical migration of gas into the atmosphere.

6) Surveys were conducted using a magnetometer and a highly sensitive methane and light gaseous hydrocarbon leak detection system over approximately 67% of the study area looking for abandoned well locations. The remainder of the area was either occupied by structures, inaccessible due to terrain/obstacles, or inaccessible due to the wishes of the landowner. Fifty two strong monopole-like magnetic anomalies were found that appear to be unmarked, abandoned wells; 14 of these were determined to be leaking stray hydrocarbon gas.

7) Initial reports of stray hydrocarbon gas problems in the study area indicated only two primary areas of concern – the 4300 block of Walnut and Third Streets and the 4700 and 4800 blocks of Second Street and Penn Way. The 14 unmarked leaking abandoned wells were found between these two areas.

8) No single option will mitigate all of the stray hydrocarbon gas problems within Versailles. The final remedy to reduce the risk to public health and safety will undoubtedly require implementation of several remedial options. Recommended options are provided later in this report. Estimated costs are also provided to assist the Borough Council and residents in determining future actions and funding requirements. The costs are considered to be reasonable engineering estimates, and should provide a sound basis for decision making. However, more detailed costs will have to be developed on a case-by-case basis once one or more of the recommended remedial approaches are adopted.

   a. NETL recommends that all existing vents be inspected and repaired or replaced, as needed, as many of them have deteriorating parts, were removed sometime in the past, contain obstructions (e.g., bird nests), have an ineffective seal with the ground, or are of insufficient height to ensure that gas is vented above adjacent structures. The cost for this option ranges from a few tens of dollars up to over several thousand dollars, per site, based on the extent of repairs.

   b. Investigations should be initiated, at a minimum, at the 14 sites where leaking gas was apparently associated with abandoned wells, to determine if excavation and venting is appropriate. Two options are presented: a non-drilling option and a drill and clean option. At some of the sites, due to the location of the well, ventilation trenches may be more appropriate than a vent placed directly over the well.

c. It is also recommended that a methane detector be installed in each building within the study area. Methane-specific alarms utilizing remote sensors and separate control boxes with audible and visual alarms are recommended for installation. The remote sensors should be installed near the ceiling in the lowest level of the structure, and the control box should be installed in the main area of the structure where the audible and visual alarms can be easily recognized. The units should alarm at concentrations between 10% and 20% of the lower explosive limit, 5% by volume, for methane. The alarms should be installed by a qualified electrician. The cost per unit for these alarms ranges from $250-300, not including installation costs. If the alarms indicate that methane is leaking into the structures, then one of several options to isolate them from subsurface methane would have to be installed. It is obviously not possible to estimate how many units would need to be treated in this manner, or how many units would be best treated using one method or the other, since such decisions have to be made on a site-specific basis.

d. It is also recommended that the Borough consider passing ordinances to ensure that gas does not accumulate under any new structures that are constructed in the Borough. Examples of ordinances from localities in California that have a similar problem have been provided. The Borough should also consider acquiring portable methane detectors, and have the supplier provide training on how to calibrate and maintain the instruments. Furthermore, considering how useful magnetometry proved to be in locating the abandoned wells, the PA DEP should consider acquiring one or more magnetometers for use at sites throughout Pennsylvania. NETL personnel can train PA DEP personnel on how to use the devices.

e. Finally, two potential long-term strategies involve removing natural gas in the subsurface and utilizing it as a resource, to prevent future migration of stray gas in the subsurface. However, these are significantly more expensive than the options listed above and may not be feasible.

9) Hydrogen sulfide ($H_2S$) was detected and measured in a few of the vented wells in the Borough and has probably been the source of the rotten egg smell periodically reported by residents. The finding of $H_2S$ was not one of the original study purposes, but it was detected during the course of this study. The apparent $H_2S$ source is the decomposition of organic materials in the wellbore water or organic materials dumped in the wellbores when they were open to the surface, though it is also possible that it could be associated with deeper strata. The occurrence of $H_2S$ appears to be limited primarily to the 4700 and 4800 blocks of Second Street and Penn Way. The $H_2S$ was only present at measurable concentrations inside the confinement of the wells themselves, not in the open air.

Hydrogen sulfide was also found in one of the two wells that we cleaned out for the video camera examination. The $H_2S$ there peaked 1 to 2 months after the cleaning was done at concentrations within the wellbore that could have been problematic if the volume of the gas was not so low. The well had a low flow rate of 6.5 $ft^3$/hr, a low well head pressure of

3.5 psi, and was filled with water to within 17 feet of the surface, creating a well bore volume of only 7.2 $ft^3$ in the 10-inch surface pipe. That well was capped the same day that the high concentrations were detected and remained closed until an $H_2S$ elimination filter was installed. Again, the $H_2S$ was only present at measurable concentrations within the confined well bore space, not in the open atmosphere. It is likely that the drilling process and circulating fluids washed organics down into the high sulfate water, which encouraged the growth of sulfate-reducing bacteria and the generation of the $H_2S$. $H_2S$ concentrations in that well have since decreased to non-detectable levels and have remained that way for the last 6 months.

In general, the $H_2S$ was only present in measurable concentrations in a few wells having low formation pressures and flow rates; its concentration in the air outside of the wells was always below the detection limits of our instruments.

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# 2.0 Approach

NETL investigated various potential sources of the methane. The original McKeesport Gas Field (which mostly drilled into the Speechley sandstone) was historically considered to be the primary source of methane leakage by migration through the high density of improperly plugged wellbores, though there were suspicions that other sources could also be contributing to gas leakage. Other primary sources included conventional gas-bearing sandstones (e.g., Elizabeth, Hundred-Foot, and Murrysville sandstones) located between the Speechley sandstone and the surface. Corroded pipe or total lack of well casing (e.g., uncased dry holes or withdrawn for World War II scrap metal drives) created gas migration pathways for these gas-bearing zones. Furthermore, it was discovered that the Murrysville or Hundred-foot sandstone may have been used as a gas storage or coke gas injection field in the area of Versailles, but available mapping only depicted its presence – not its boundaries. State records indicate that the storage or injection terminated in the 1950's. Seismic tests did not indicate any large volumes of gas remaining at those depths.

Other potential sources of methane leakage were also investigated. One potential source of methane suggested by a few local residents was the Hubbard Coal Mine. This coal mine, which is located in the Upper Freeport coal seam and about 200 feet in depth beneath the surface, opened shortly after the gas boom and closed in the early 1960's. Although the presence of the coal mine was well known, the actual boundaries and other facts were initially unknown to the investigators and many of the residents. Mine maps acquired early in the study showed that the actual underground workings circumvented the Borough of Versailles to the north. The fact the Borough was not undermined may have been due to the high density of wells within the Borough. Consequently, the high density of wellbores within Versailles intercepts not only the various traditional gas-bearing sandstones (depths of 2,000 to 3,000 feet), but also intercepts the solid Upper Freeport coal, known to contain methane gas, as well as other geologically lower coal seams. Finally, early discussions with regional gas industry personnel exposed the fact that although hydrocarbon chemistry can typically "fingerprint" a particular gas source (sandstone or coal seam), the Murrysville sandstone and Upper Freeport coal seam are indistinguishable in terms of gas analyses. Consequently, the approach looked at alternative efforts to differentiate the possible sources.

In general, the approach involved investigating and characterizing the subsurface and surface to acquire a better understanding of this complex setting. More specifically, a number of investigations were conducted in this study, including: geophysical surveys (seismic and magnetic technologies), literature and newspaper searches, examination of historic maps and photographs, analysis of soil maps, meetings with local oil and gas industry personnel, personal interviews with Borough residents and officials, creation of maps and databases, gas analyses from existing vents and wells, re-entering two abandoned gas wells, and searching for unknown gas leaks and hidden wells.

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# 3.0 Study Findings

The study was limited to an area within the Borough where known methane gas leakage problems were reported to exist. This limited the study area to roughly a one-half mile long by one-quarter mile wide area bounded to the north by the McKeesport city limits, to the east by Walnut Street, to the south by the Boston Bridge, and to the west by the Youghiogheny River (Figure 6). Although the basis for the study area was defined by the Borough and input from local residents, this does not mean that structures outside the study area are safe from stray methane gas.


**Figure 6.** Map showing the location of the Versailles Borough stray gas study area.

## 3.1 Seismic Surveys

Subsurface seismic investigations were conducted, including marine seismic surveys within the Youghiogheny River and shallow three-dimensional seismic surveys along the streets within the Borough (Figure 7). Results from all of the seismic surveys were inconclusive as to the ultimate source of the emanated stray gas. Although inconclusive, the seismic surveys tend to support


**Figure 7.** Locations of three-dimensional seismic lines in Versailles Borough.

other findings within this study that the gas may be emanating from multiple sources. No major fractures or faults that could be pathways for natural gas from underground were identified, though some less significant gas-filled fractures were detected under the riverbed. Given the highly disturbed surface materials and underground infrastructure adjacent to and under the Borough streets, such features might have been masked in the town.

## 3.2 Vent Gas Analyses

Laboratory analyses were conducted on stray gas emanating from 30 existing vents and six abandoned wells within the Borough (Plate 2) and from a known Speechley sandstone production well near East Allegheny High School, approximately five miles from the Borough. Analyses were run for C1 through C4 hydrocarbons: methane (C1), ethane (C2), propane (C3), and butane (C4). Based on these analyses, it was determined that gas from the vents known to be attached to or associated with old wells contained 98% or higher methane content based on percentage of each of the tested hydrocarbons. Gas analysis of the Speechley well showed 96% methane with higher amounts of the C2 – C4 constituents (Figure 8).

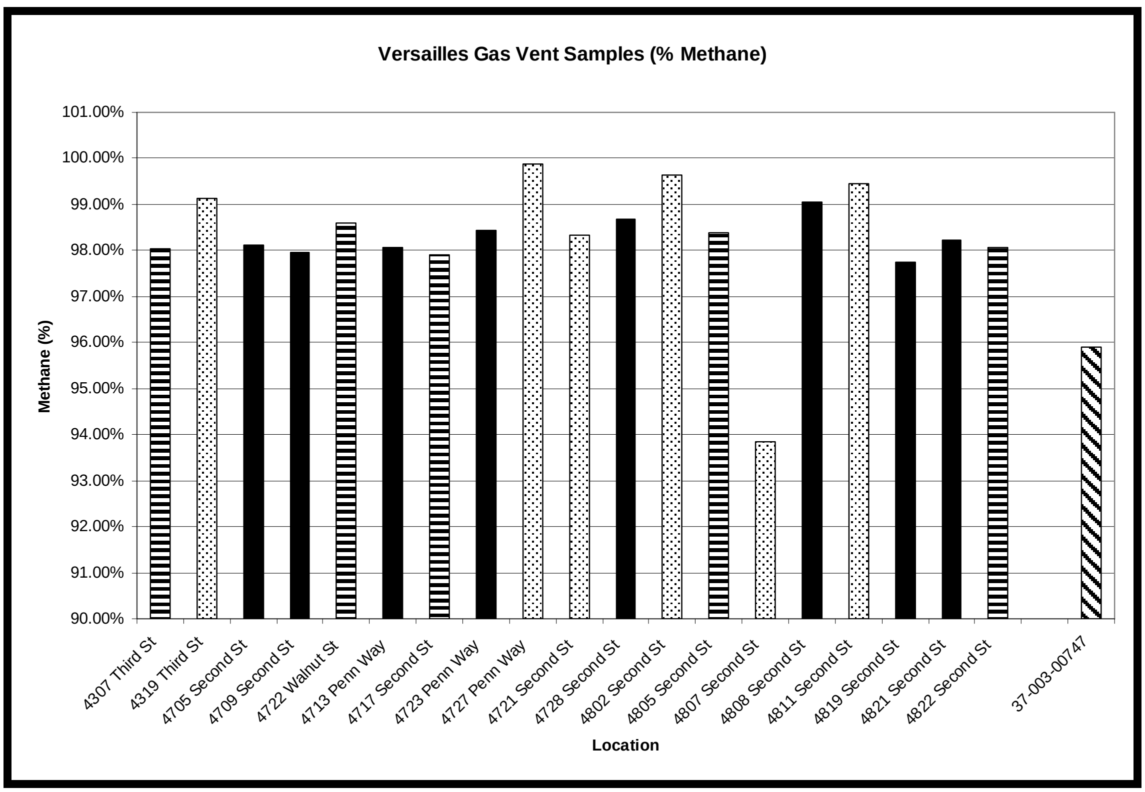


**Figure 8.** Percent methane in sampled Versailles vents. Solid bars are vents over known or suspected wells, dotted bars are vents over areas that have had gas in the past, bars with horizontal lines are wells/vent with measurable gas flows, and the cross-hatched bar is a known Speechley producing well at East Allegheny High School.

Pure methane gas has no odor. Gas utility companies add an odorant, mercaptan, so that gas can be detected in a home or business in case of leakage. The occasional rotten egg odor reported by some residents would suggest the presence of hydrogen sulfide ($H_2S$) in the stray gas. The $H_2S$ could be attributed to anaerobic (absence of oxygen) digestion from the bacterial breakdown of organic matter, such as occurs in swamps and sewers, but it also occurs naturally in well water and natural gas.

Review of the hydrocarbon profile from the analytical data obtained from vents associated with known old gas wells indicated the C1:C2+ ratios were consistent with natural gas of Upper Devonian origin. Stable carbon and hydrogen isotope data for stray gas samples collected at two locations by the PA DEP in 2004 support this interpretation (Fred Baldassare, personal communications, 2007). Specific origin of the stray gases is unknown and was beyond the scope of this investigation. However, natural gas production history for the study area reveals that the Speechley sandstone and shallower Elizabeth, Murrysville, and Hundred-foot sands were productive of gas in the area. Stray hydrocarbon gases detected at the surface in Versailles Borough is likely a mixture of gases from some combination of these producing intervals of Upper Devonian origin. Gas from the Upper Freeport and other coal seams may also be contributing to the stray gas problem at the surface as gas moves vertically up the improperly abandoned wellbores. Improper well abandonment for many of the 175 gas wells drilled in the Borough provides a mechanism of migration for stray gas detected at the surface.

Many of the vents were found to not be attached to old wells, but were placed in yards or adjacent to structures where gas “hot spots” had been located during previous studies. Gas emanating from the vents and old abandoned wells has very low surface pressure (generally only a few pounds per square inch, psi) and, in most cases, low production rates, less than 0.5 cubic feet per hour ($ft^3/hr$). A total flow rate of about 70 $ft^3/hr$ was found from all existing vents and wells within the study area (Table 1). One well, located at 4805 Second Street, was producing 50 $ft^3/hr$ (1.2 Mcf/day) of the total 70 $ft^3/hr$. Since seismic surveys had been inconclusive in determining gas migration pathways, two old wells were reopened and cleaned down through the coal intervals. One well was located on a vacant lot at 4722 Walnut Street; the second well was located at 4822 Second Street on a vacant lot adjacent to the Borough garage. Gas flow rates after wellbore cleanout were 10.0 and 6.5 $ft^3/hr$, respectively. The locations of these wells are shown on Figure 9.

**Table 1.** Locations of vents and old wells having measurable gas flows.

| **Location** | **Flow Rate ($ft^3/hr$)** | | **Type** |
|---|---|---|---|
| | Initial Rate | Post Clean-out | |
| 4307 Third Street | 20.0 | not applicable | Vent over Well |
| 4717 Second Street | 3.5 | not applicable | Vent |
| 4805 Second Street | 50.0 | not applicable | Vent over Well |
| 4822 Second Street | ≈ 0.5 | 6.5 | Well |
| 4722 Walnut Street | ≈ 0.5 | 10.0 | Well |

### 3.3 Hydrogen Sulfide ($H_2S$) Detection

Prior to opening the old wellbores at the Borough garage or Walnut Street, a survey was conducted in early September to determine the source of the occasional rotten egg smell reported

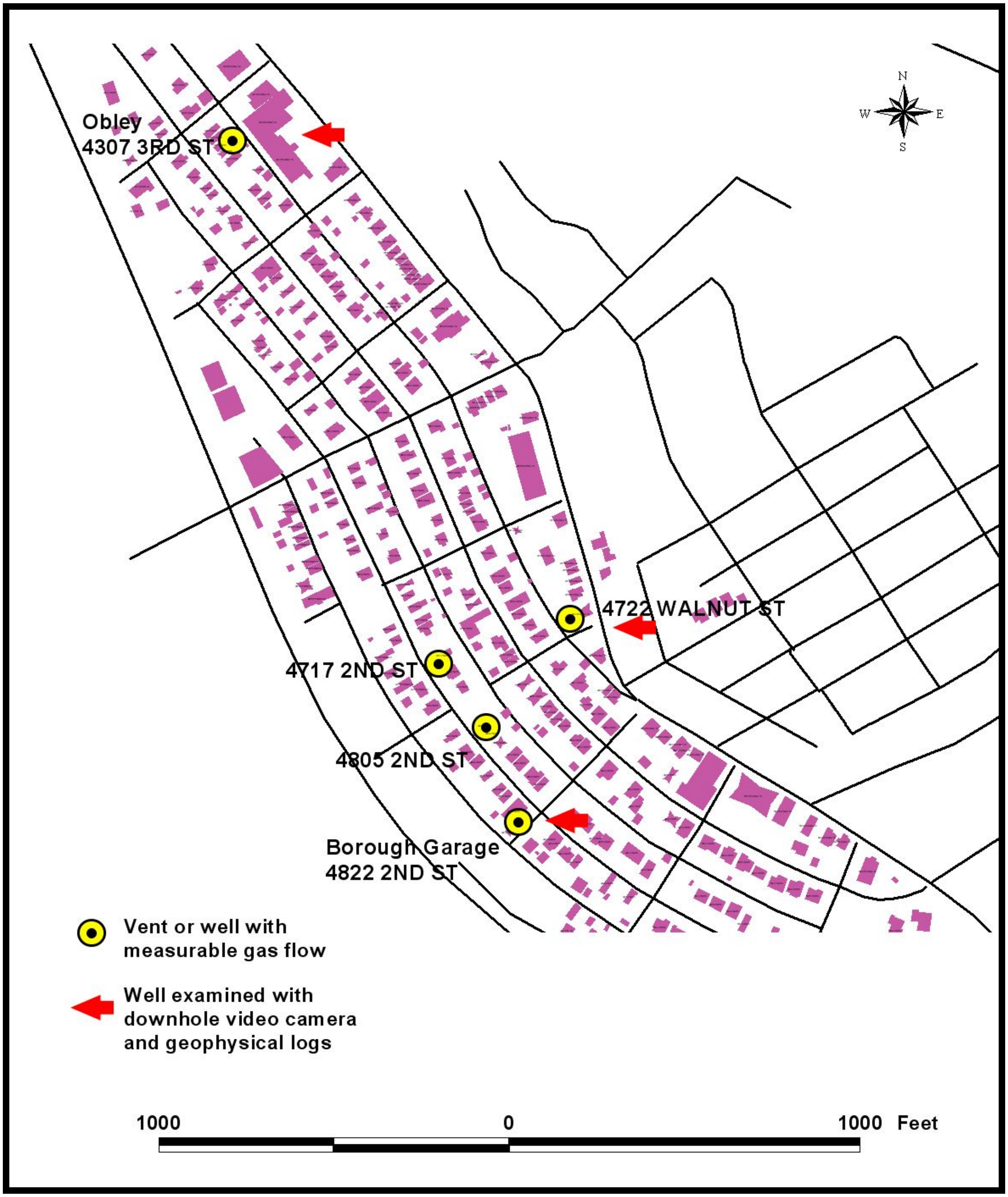


**Figure 9.** Locations of wells producing gas flow rates in excess of 0.5 cubic feet per hour, and wells that were examined with the down-hole video camera and geophysical logs.

within the Borough by local residents. Surveys taken with the Passport multi-gas detection unit indicated that the source was hydrogen sulfide ($H_2S$) emanating from two vents – 4705 Second Street (1 ppm) and 4821 Second Street (17 ppm). Both of these values were well below the National Institute of Safety and Health (NIOSH) Immediately Dangerous to Life and Health (IDLH) level of 100 ppm. A third vent at 4819 Second Street was reported by Borough residents as sometimes having a sulfur odor, but the vent was too high to reach safely to take a measurement.

Drilling began at the Borough garage well on September 21, 2006 and ended on October 6, 2006. On October 24, the well was producing 13 ppm $H_2S$. A reading taken of the wellbore gas on November 15 indicated an $H_2S$ reading of 118 ppm, exceeding the IDLH level of 100 ppm. That same day, the well was shut-in (all gas venting was terminated) and the Borough Street Maintenance personnel using the garage, Borough security, and Borough office personnel were all notified that the well was producing high levels of $H_2S$, that the well had been shut-in to avoid any escape of the $H_2S$ to the atmosphere, and to not reopen the well. Notifications were also made that day to the PA DEP Oil and Gas Division and RDS Environmental Safety and Health (ES&H) personnel apprising them of the situation and the actions taken. Although the level inside the wellbore reached an unsafe level, the gas dispersed in the open atmosphere to a near zero reading within a couple feet of the wellbore. The well was flowing at a rate of only 6.5 $ft^3/hr$ and had shut-in surface pressure of only 3.5 psi. Due to the low flow rate, the height of the vent above ground level, and its dispersion rate in the open atmosphere, area Borough residents were never in jeopardy from the produced $H_2S$. Measurements taken at the vent at 4821 Second Street remained at 17 ppm during the increased $H_2S$ levels in the Borough garage well.

A $H_2S$ removal system was researched and a $H_2S$ removal cartridge was ordered to allow the well to be safely reopened to the atmosphere. While waiting on the $H_2S$ removal cartridge to arrive, the $H_2S$ level inside the closed well peaked at 331 ppm (laboratory sample); however, at no time was the public in any danger since the well was sealed from the atmosphere. Ambient air samples taken by RDS ES&H personnel showed that the $H_2S$ levels were below detection limits within a couple feet of the well, even when taking samples, due to the well's low flow rate and atmospheric dilution. The $H_2S$ removal cartridge was installed on the well on December 11, and the well was reopened to the atmosphere. No $H_2S$ was detected at the output end of the cartridge. By December 13, the $H_2S$ in the wellbore had dropped from the high of 331 ppm to 104 ppm as detected by the Passport multi-gas meter. By March 21, the $H_2S$ level in the wellbore had dropped below detection limits, as determined by sampling with the Passport multi-gas meter, and it has remained at that level through the duration of the project. The $H_2S$ removal cartridge was left on the wellhead in case any additional $H_2S$ was produced in the wellbore after the project was completed. RDS ES&H personnel were on site with monitoring and safety equipment during all sampling and work on the Borough garage wellbore until the well dropped to undetectable $H_2S$ readings in March. All $H_2S$ readings taken during video camera surveys, geophysical well logging, and installation of wellbore casing were in the safe range over the open wellbore and dropped below detection limits within a couple feet of the wellbore.

Hydrogen sulfide often results from anaerobic bacterial digestion, the bacterial break down of organic matter in the absence of oxygen, such as occurs naturally in swamps and sewers. It also sometime occurs in natural gas and some well waters. The $H_2S$ in the Borough garage well could thus be coming from a multitude of sources. The wellbore, when opened and drilled, contained pieces of old wood and bricks that had remained underwater since the well had been temporarily sealed many years ago (exact date is unknown). This debris, along with any other trash placed in the open wellbore before it was sealed, may have produced some $H_2S$ gas when exposed to the fresh water drilling fluids. The water used to drill out the rubble in the old wellbore was obtained from a nearby fire hydrant. The water in the hydrant had obviously been there for a long period of time as it contained what appeared to be a combination of mud and iron residue. The steel water storage tank and portable mud pit used for drilling had lain dormant for a period of time and could also have contained bacteria and some organics (e.g., algae). Hydrogen sulfide may be occurring naturally at very low levels in the stray natural gas, but it appears that its concentration was increased by the drilling activity and increased flow rate. The delay between the cleaning and the high concentrations is presumably due to the time it took for the sulfate-reducing bacteria to reach high concentrations.

### 3.4 Down-hole Video Surveys

Gas was visibly seen emanating from the Upper Freeport coal seam in the Walnut Street well using the down-hole video camera after the well was cleaned to below the coal seam. Gas bubbles were not present below the Upper Freeport seam. Casing was installed in the well immediately above the Upper Freeport seam using an open-hole packer. Lack of gas flow or pressure in the annulus (casing exterior) after casing installation indicated the gas migration pathway in this well was limited to the Upper Freeport coal and that the gas had not migrated to any of the overlying formations. Based on the findings within this well, gas appears to be migrating from deeper formations within one or more old wells in the immediate area and moving laterally within the Upper Freeport coal seam. Once in the coal seam, the gas utilizes the abandoned wellbores to migrate to the surface, making each wellbore a potential gas emanation point source.

In the lower elevation part of the Borough in the 4700 and 4800 block area of Penn Way and Second Street, another gas migration pathway appears to exist based on down-hole video surveys from the Borough garage well at 4822 Second Street. Gas bubbles were visible to a depth of 65 feet. Unlike the Walnut Street well, the exact entry point could not be determined due to the amount of fine clay and coal fragments held in suspension in the wellbore water. However, since no gas bubbles were evident below a depth of 65 feet, the gas is most likely emanating from the shallow Buffalo sandstone, which is present in the wellbore from an approximate top depth of 17 feet to a bottom depth of 65 feet. This was further substantiated when casing was run in the wellbore. Casing was run on an open hole packer in the wellbore, but at every set point from the top of the Upper Freeport coal to inside the old surface conductor, gas was found on the outside of the casing (annulus) and not within the casing. The inability to seal off gas from the annulus in the Borough garage well indicated that methane gas was not emanating from the Upper Freeport coal seam as seen in the Walnut Street well, but was entering from the Buffalo sandstone formation into the wellbore through the rusted out surface conductor casing. Horizontal migration of the gas in the Buffalo sandstone close to the surface (less than 20 feet) may account for the widespread methane gas problem in the 4700 and 4800 blocks of Penn Way and Second Street including gas within several yards and within or adjacent to the roadways. Based on field magnetometer and gas detection surveys, the old wellbores are the primary source for the vertical migration of the stray gas to the surface in this area, especially where casing remains to the surface. However, where casing is absent at the surface, the stray gas tends to migrate away from the old wellbore into the surface soils. The sandy A-2 and R-7 soil types in the area (Figure 10), derived from weathering of the underlying sandstone and lying within a former floodplain of the

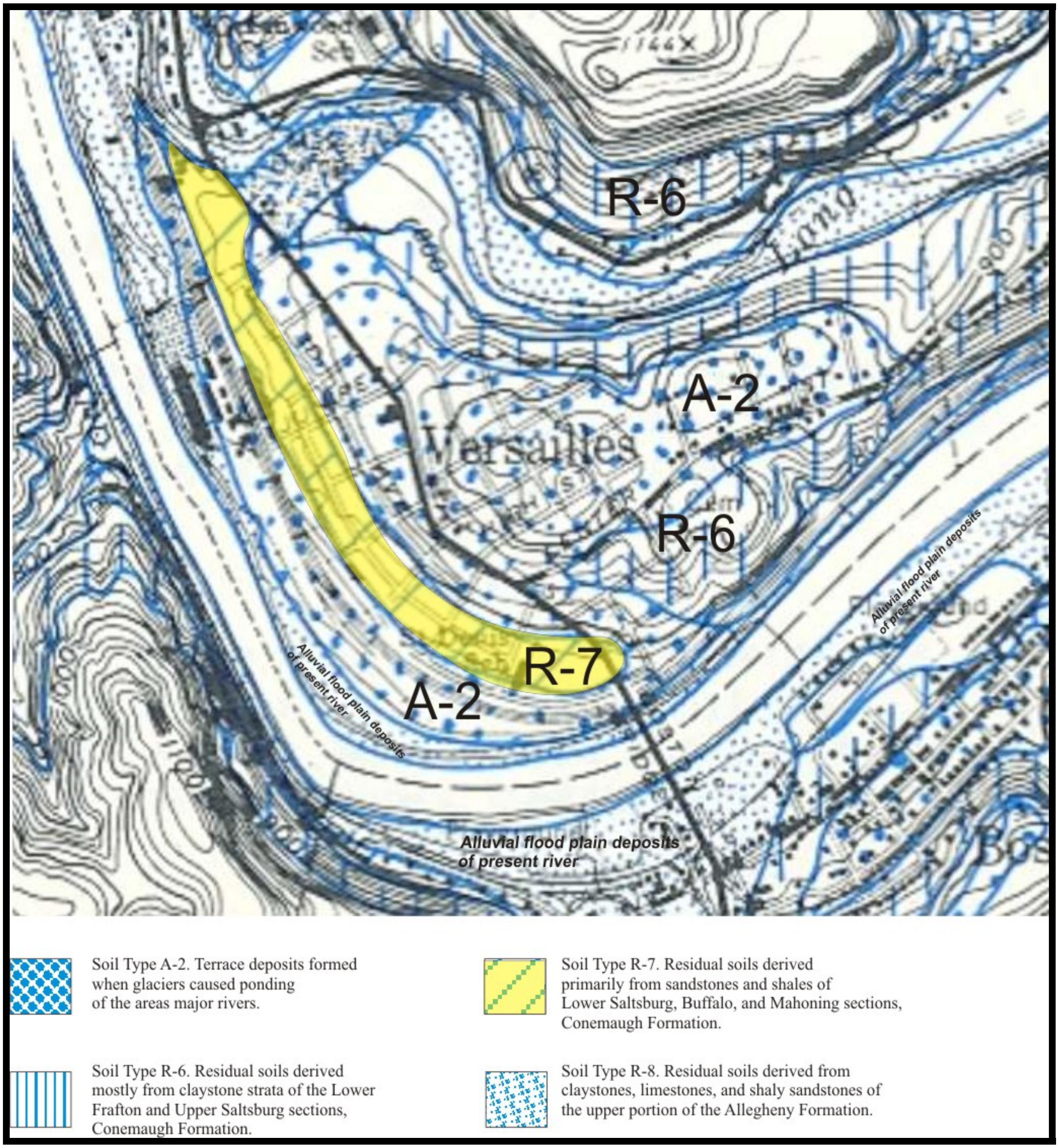


**Figure 10.** Soil map of Versailles region from Ackenheil (1968). Soil types R-7 and A-2 would be expected to have a lower clay content and potentially higher potential for vertical soil gas migration.

Youghiogheny River, may be contributing factors. Local residents reported that the gas leakage problem is worse during wet weather, which meshes with our observations. During dry weather, the gas can migrate up the old wellbores into the soil, and then into the atmosphere. During wet weather conditions, water fills the upper pore spaces within the soils, forcing the migrating gas to move laterally into structural foundations and back into the abandoned wells instead of continuing the vertical movement into the atmosphere. Similar situations may occur during periods of barometric high pressure, keeping the low-pressure stray hydrocarbon gas retained in the soils.

Although not one of the cleaned-out wells, a down-hole video survey was run on the well at 4307 Third Street. Methane gas problems associated with the well appear to be related to gas coming up the back (annulus) of the smaller diameter casing left in the hole at a depth of 44 feet. At this point, the smaller casing is separated from the larger (6-inch) surface casing, allowing gas to migrate into the surrounding permeable geologic formations. The well currently has an electric blower attached to the vent, which helps the gas move up the well and out to the atmosphere; however, gas could still be leaking into the geologic formations below a depth of 44 feet. The relationships of all three wells with respect to the Upper Freeport coal seam, Buffalo sandstone, and top of the area water table are shown in Figure 11, and Plate 3.

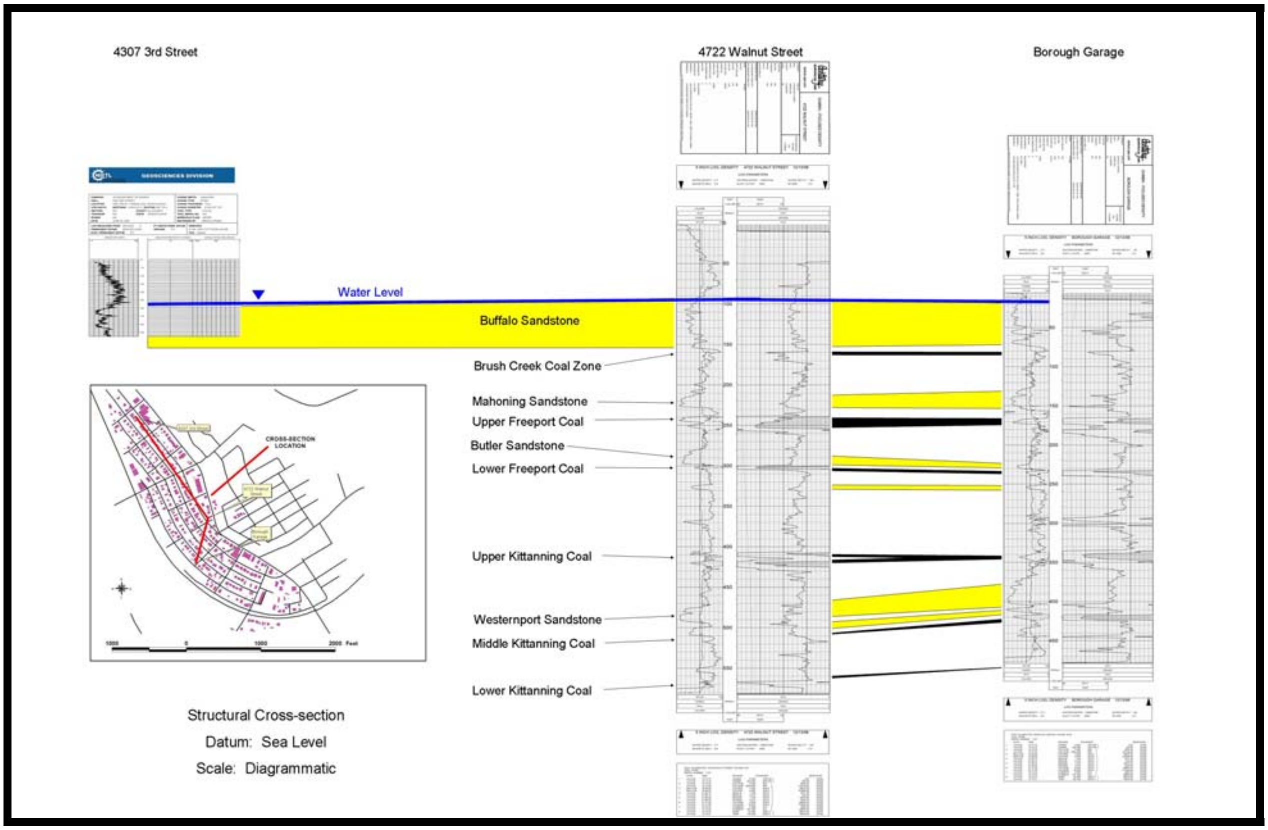


**Figure 11.** Geologic cross-section between the Borough Garage, Walnut Street, and 4307 Third Street wells. Note depth of water table in all wells near the top of the Buffalo sandstone.

### 3.5 Methane Buster™ Testing

The Methane Buster™ is a six-cylinder gasoline engine that has been converted to run on methane gas, equipped with a blower assembly, and designed to degasify coal seams prior to mining operations. It was tested as a potential remedial option to eliminate the methane gas leak within the Borough by pulling a vacuum on a producing well. Since the Methane Buster™ runs on methane gas, it can sustain itself on the methane produced from a well or series of wells. In the tested configuration, it required approximately 180 $ft^3$/hr of methane. This demand could not be met by any of the wells in Versailles Borough, so for testing purposes, a propane tank was installed on the Walnut Street well. The Methane Buster™ was found to increase the volume of gas that could be extracted, but required lowering the water level in the well to reduce the hydrostatic pressure on the produced gas. Slightly more than an order of magnitude increase (10 to 120 $ft^3$/hr) in gas volume was noticed by reducing the hydrostatic pressure approximately 75 pounds per square inch (psi) on the Upper Freeport coal seam at the Walnut Street well.

Samples were taken of the produced well water and water from the Youghiogheny River to determine if the produced well water could be entered into the local storm sewer without treatment. Laboratory results (Table 2) indicated the well water was high in sodium (Na) and chloride (Cl) ions. The high Na and Cl content suggests that the source may be salt water from deeper formations. Gallagher (1973), found that salt water under artesian pressure has over the years migrated up old boreholes and out into the shallower freshwater aquifers in Allegheny County. This was attributed to the intense drilling for oil and gas in the past and the fact that many of the old casings have been removed or have become severely corroded. The water analysis also indicated that the produced well water was relatively high in several metal ions, including aluminum (Al), barium (Ba), iron (Fe), magnesium (Mg), and strontium (Sr). These contaminants may have been, in part, derived from the coal. The sample was also relatively high in silicon (Si), presumably due to weathering of silicate minerals from the sandstone formations. Because of all these factors, the water could not be placed directly into the river and was therefore collected in a portable tank and hauled away for disposal at an approved disposal site.

Gas volume decreased from 50 $ft^3$/hr to 35 $ft^3$/hr at a vent believed to be attached to an old well at 4805 Second Street while water was being pumped and the Methane Buster™ tested at the Walnut Street well. This suggests interconnectivity between the two areas and that increasing methane gas extraction from a point source pulls gas from a larger area. This favors the possibility of extracting gas from underground. However, costs associated with treating and/or hauling saline water would be expensive, especially since there does not appear to be marketable amounts of gas. One of the remediation options is the extraction of gas from the Buffalo sandstone, but this would require some preliminary drilling to determine how much, if any, water would have to be pumped and what quality water is present in that stratum.

### 3.6 Targeting Unmarked Abandoned Well Locations

Magnetic and sensitive methane surveys were used successfully to target many potential unmarked abandoned wells in Versailles Borough. Using a Geometrics G-858 cesium ion magnetometer, over 27 line miles of magnetic data were collected over an urban study area of approximately 40 acres. A combination of magnetic and methane data were acquired over

**Table 2.** Analysis of Versailles water samples from the Walnut Street well. A sample was also taken from the Youghiogheny River for comparison.

| Versailles Water Samples, sampled 4/18/07 | | | | | | |
|---|---|---|---|---|---|---|
| analyzed 4/19/07 | | Optima 3000 | *note larger units for Ca and Na* | | | |
| **ICP-OES** | | **Versailles, FA** | **Versailles A avg** | **River A avg** | | ***det limits*** |
| **Ag** | ug/L | < DL | < DL | < DL | **Ag** | *< 5* |
| **Al** | ug/L | 19.2 | 2928 | 490 | **Al** | *< 15* |
| **As** | ug/L | < DL | < DL | < DL | **As** | *< 8* |
| **B** | ug/L | 137 | 161 | < DL | **B** | *< 25* |
| **Ba** | ug/L | 3047 | 3338 | 41.9 | **Ba** | *< 1* |
| **Be** | ug/L | < DL | 0.44 | 0.16 | **Be** | *< 0.1* |
| ***Ca*** | *mg/L* | *76.3* | *84.7* | *16.6* | ***Ca*** | *< 0.010* |
| **Cd** | ug/L | < DL | < DL | < DL | **Cd** | *< 1* |
| **Ce** | ug/L | < DL | < DL | < DL | **Ce** | *< 80* |
| **Co** | ug/L | < DL | 3.8 | < DL | **Co** | *< 3* |
| **Cr** | ug/L | < DL | 6.4 | < DL | **Cr** | *< 3* |
| **Cu** | ug/L | < DL | 18.0 | < DL | **Cu** | *< 4* |
| **Fe** | ug/L | 3281 | 10460 | 968 | **Fe** | *< 3* |
| **K** | ug/L | 7578 | 8748 | 1275 | **K** | *< 45* |
| **Li** | ug/L | 36.6 | 43.4 | < DL | **Li** | *< 9* |
| **Mg** | ug/L | 18510 | 19590 | 4451 | **Mg** | *< 3* |
| **Mn** | ug/L | 78.4 | 123 | 120 | **Mn** | *< 1* |
| **Mo** | ug/L | < DL | < DL | < DL | **Mo** | *< 3* |
| ***Na*** | *mg/L* | *1803* | *1897* | *16.3* | ***Na*** | *< 0.025* |
| **Ni** | ug/L | < DL | 10.3 | 4.5 | **Ni** | *< 4* |
| **P** | ug/L | < DL | 58.3 | 35.0 | **P** | *< 15* |
| **Pb** | ug/L | < DL | 18.2 | < DL | **Pb** | *< 5* |
| ***S*** | ug/L | 1443 | 1525 | 10565 | ***S*** | *< 25* |
| **Sb** | ug/L | < DL | < DL | < DL | **Sb** | *< 6* |
| **Se** | ug/L | < DL | < DL | < DL | **Se** | *< 8* |
| **Si** | ug/L | 3005 | 6358 | 2065 | **Si** | *< 100* |
| **Sn** | ug/L | < DL | < DL | < DL | **Sn** | *< 15* |
| **Sr** | ug/L | 2032 | 2147 | 69.8 | **Sr** | *< 1* |
| **Ti** | ug/L | < DL | 32.8 | 3.8 | **Ti** | *< 1* |
| **Tl** | ug/L | < DL | < DL | < DL | **Tl** | *< 12* |
| **V** | ug/L | 4.3 | 4.9 | < DL | **V** | *< 2* |
| **Zn** | ug/L | < DL | 48.2 | 25.4 | **Zn** | *< 3* |

| | | |
|---|---|---|
| **Cl** | ppm | 2272 |
| **pH** | su | 7.35 |
| **Alkalinity (as $CaCO_3$)** | mg/L | 570 |

**Table 2 Notes:**

- Filtered acidified sample analyzed as received for dissolved metals.
- Acidified samples were digested according to EPA Method 3005 for total metals.
- Na analyses were performed on Versailles samples diluted 50x with water.
- Some metals analyzed by ICP-OES and others by ICP-MS (mass spec), which has much lower detection limits (DL).
- The chloride content (by ion chromatography), pH, and alkalinity of the well water were measured in the lab and listed in the small sub-table beneath the main table.
- FA means filtered (0.45um) acidified and A designates samples that were just acidified without filtration.
- The pumping entrained a fair bit of gray sediment and from the analysis of filtered and unfiltered samples - it appears the sediments contain mainly Al, Fe, and Si.

approximately 67% of the available study area. The remainder of this area was either occupied by structures, inaccessible due to terrain/obstacles, or inaccessible due to the wishes of the landowner. The magnetic amplitudes of the suspected well anomalies were usually in excess of the geomagnetic total field value by at least 5,000 nanoteslas (nT) and sometimes as high as 30,000 nT.

Individual surveys were short in duration (less than 15 minutes); therefore, it was not necessary to compensate for the diurnal variation of the Earth's magnetic field. Position information was acquired alongside the magnetometer by employing a Trimble AG132 global positioning system (GPS) with a multi-path resistant antenna, operated in differential mode augmented by OmniSTAR® supplemental differential correction service for increased accuracy. In this configuration, the location of the suspected unmarked abandoned well could generally be mapped with an accuracy of +/- 0.9 meters (approximately 3 feet).

Numerous magnetic surveys were conducted in the residential lots of Versailles Borough (Plate 4). Surveys were conducted on the individual lots by walking a serpentine course in a direction parallel to the longest dimension of each property. Priority was given to surveying the largest contiguous area within the lot that permitted the most unobstructed path. In some lots, the largest contiguous survey area would not allow the collection of more than three adjacent parallel swaths; either single line profiles were collected, or the instrument was operated in search mode, in which case no data was logged. Search mode was also used to both target and more precisely determine the position of anomalies discovered during a regular serpentine survey and in the final reconnaissance. This was accomplished by observing the magnitude of the digital total field readout in conjunction with the strip chart graphic display on the instrument console while sweeping a small area with the magnetometer sensor above the target at a constant height.

One of the most important results from this study was the identification of 52 very strong monopole-like magnetic anomalies in excess of 5000 nT above the earth’s geomagnetic total field intensity in Versailles Borough (Figure 12, Plate 5). The only way to confirm whether or not these anomalies are all unmarked abandoned wells is by excavation. Permission was only obtained to excavate one magnetic anomaly, which did indeed prove to be a well, located at a depth of 2-3 feet below the surface.

The Apogee Scientific leak detection system (LDS) was found to be a highly sensitive methane and light gaseous hydrocarbon detector. The LDS works on the principle of infrared absorption. The LDS is tuned to monitor an absorbance wavelength specific to methane ($CH_4$), but will also simultaneously monitor other light hydrocarbons and carbon dioxide ($CO_2$). The collective response of the higher molecular weight hydrocarbons (C2 – C6) is referred to as total hydrocarbons. The instrument is capable of measuring these species in near real time and at very low detection limits (0.2 ppm, parts per million). The GPS position of each leak is reverse geo-coded to provide a street address.

A custom software application developed at NETL was used to extract methane peak data based on width (samples) and threshold amplitude (concentration) in a Geographical Information Systems (GIS) compatible format. The GIS database contains the imagery and other mapping data layers that were used to select leaking potential well targets from the magnetic data sets through correlation with methane concentration data based on a spatial proximity analysis.

Areas containing a high density of abandoned gas wells that were leaking could be identified simply by driving the streets, with the Apogee LDS mounted in a truck. The results of the street survey are shown in Figure 13. Close examination of the color-coded concentration profiles in Figure 13 shows that methane plumes can be observed. In fact, consecutive surveys performed after a shift in wind direction reveals that certain sources persist for considerable distances. Ideal survey conditions are when the survey direction is upwind and crosswind to the source and when the wind direction doesn't change during the survey. It soon became apparent that ideal conditions seldom occur. Wind direction can suddenly change and obstruction-induced turbulence along with eddy currents can further complicate interpretation of the methane plumes, due to partitioning and dilution. This truck-mounted approach of targeting potential unmarked abandoned wells using the Apogee LDS had to be revised in order to distinguish between low volume methane sources and a transient plume intercepted from a nearby vent. The instrument had to be brought closer to the source of leaking methane.

Therefore, the Apogee LDS was mounted in a lightweight folding cart constructed of aluminum (Figure 14). The air induction system was modified so that sampling would occur through a pipe mounted about 10 centimeters (4 inches) above the ground. To avoid contamination, the sensitive optical elements were protected by two automotive type cylindrical air filter elements mounted in series on the intake side of the induction system. Input from a mass air flow sensor was used to compensate for irregularities in induction rate due to obstructions that could otherwise affect the response. Employing the cart-mounted implementation of the Apogee LDS instrument, several methane plumes could be traced to their sources, which were mainly passive gas vents, some of which were mounted on top of known abandoned gas wells. Fourteen of the 52 magnetic targets interpreted as unmarked abandoned wells were associated with elevated methane levels measured using the Apogee LDS methane and light hydrocarbon detector mounted on a cart and sampling the air close to ground level (Plate 6). These unmarked abandoned wells were leaking methane gas in areas between the two known methane leak problem areas (Table 3). This would indicate that the problem area extends across most of the area below Walnut Street.

Almost all of the methane found in the initial air plume study or using the cart-mounted sensor was found to be associated with storm sewers, small leaks around gas meters, or locally elevated levels near vents or the 14 magnetic indications of unmarked abandoned wells. Low levels of dispersed methane were sometimes detectable emerging through the soil at some sites. The highest measured methane concentration (13.6 ppm) in the Apogee LDS street survey was traced to a sanitary sewer vent. None of the measured concentrations came remotely close to the lower explosive limit for methane (approximately 50,000 ppm).

**Table 3.** Summary of methane leaks found near selected magnetic targets interpreted as unmarked abandoned wells.

| Magnetic Target Description | Coordinates (WGS-84, UTM zone 17, meters) | |
|---|---|---|
| | Easting | Northing |
| 4912 2nd Street | 599067 | 4463387 |
| 4801/4807 3rd Street | 599076 | 4463563 |
| 4806 3rd Street (well excavated 02/01/2007) | 599029 | 4463537 |
| 4822 2nd Street (municipal garage well excavated) | 599024 | 4463429 |
| 4319 3rd Street (under red brick sidewalk) | 598808 | 4463988 |
| 4909 3rd Street | 598783 | 4463999 |
| 4415 2nd Street (methane near 4in steel vent pipe) | 598812 | 4463842 |
| 4708 2nd Street | 598904 | 4463594 |
| 4626 Walnut Street (Larch & Sumac, SW of Apartment complex) | 599020 | 4463699 |
| 318 Juniper Street (asphalt parking lot) | 599020 | 4463814 |
| 4722 Walnut Street (reworked well, Methane Buster™ test site) | 599070 | 4463602 |
| 4710 Penn Way | 598923 | 4463581 |
| 4806 2nd Street (steel plate covering depression, target 9 m NE) | 598969 | 4463492 |
| 4611 2nd Street (strong anomaly under concrete walk) | 598906 | 4463703 |

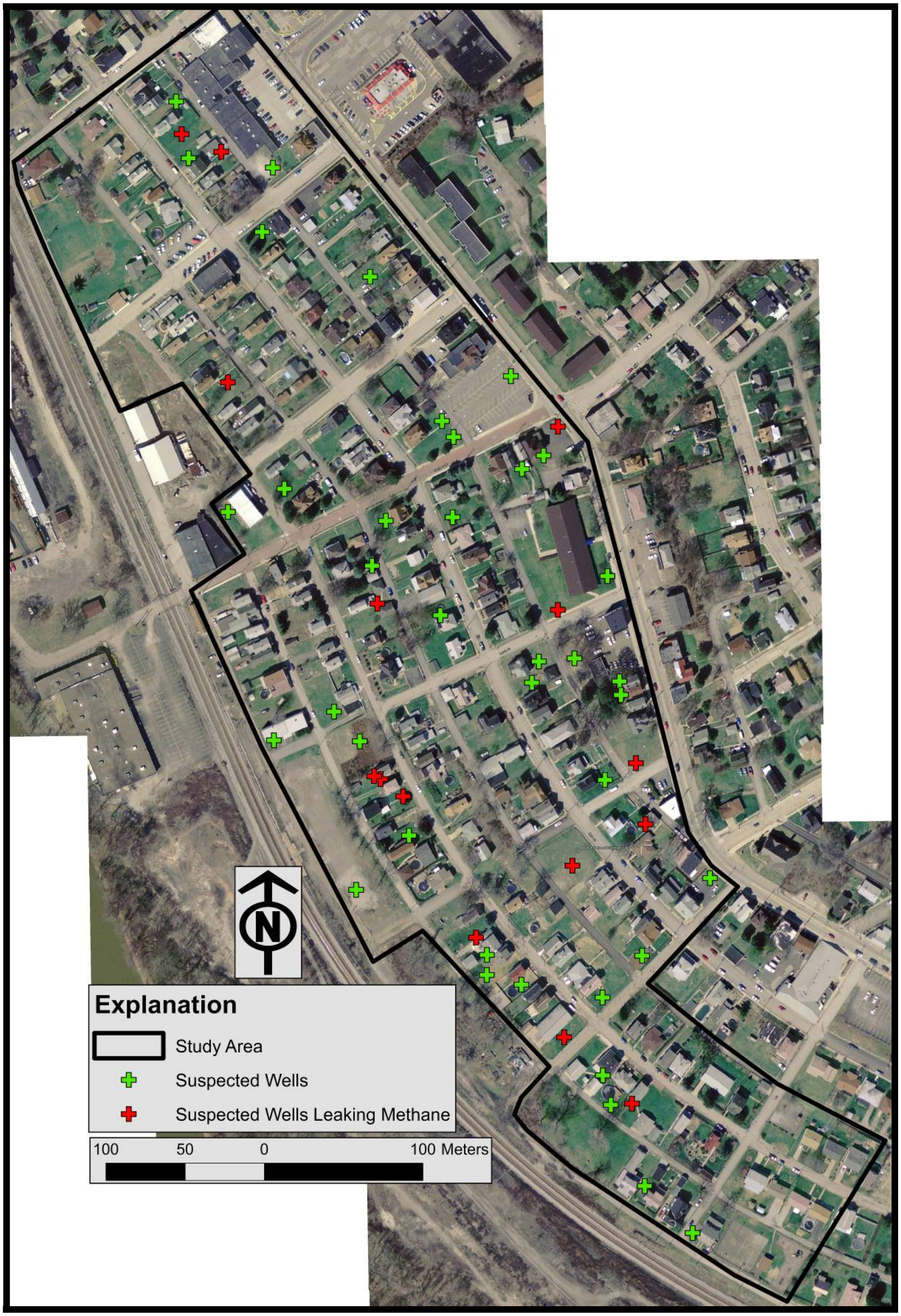


**Figure 12.** Suspected unmarked abandoned wells located using magnetic methods and methane detection.


**Figure 13.** Results from an Apogee LDS survey of Versailles Borough. Methane concentrations along the vehicle GPS track are represented by graduated symbol and color. The magenta symbols are the GPS locations of passive vents. Some vents are associated with abandoned gas wells.

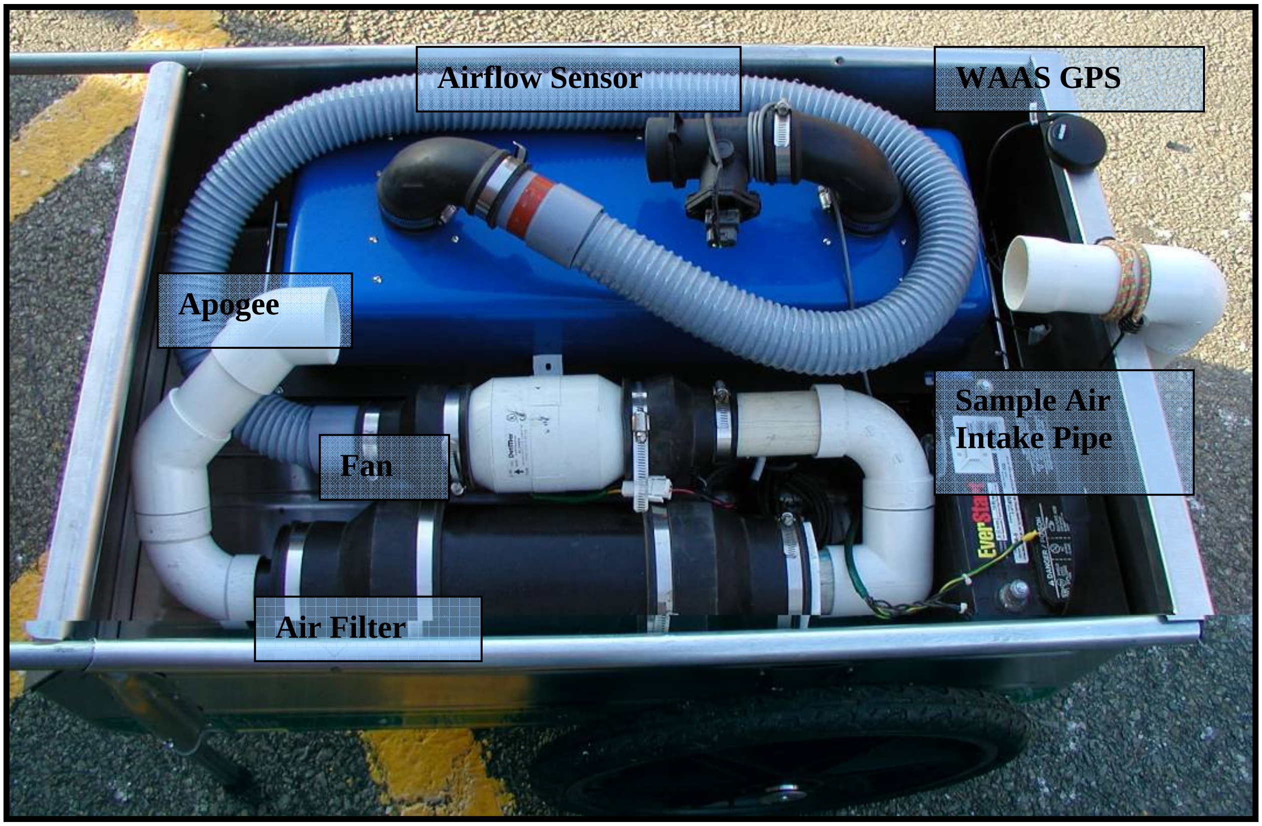


**Figure 14.** Apogee LDS methane and light hydrocarbon instrument mounted in a light-weight aluminum cart. The intake hose was removed for clarity as was the ruggedized tablet computer data system.

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## 4.0 Conclusions

Results of the field investigations, gas sampling, seismic surveys, Methane Buster™ tests, and subsurface unmarked abandoned well detection surveys can be summarized in the following conclusions:

1) Over 175 wells were drilled in Versailles Borough between 1919 and 1921 as part of Speechley sandstone gas drilling in the McKeesport Gas Field. Many of these wells were drilled in close proximity to houses. The field was over-drilled, over-produced, and rapidly went to depletion. Depleted wells and dry holes were left abandoned and unplugged. During the steel scrap drive of World War II, most of the casings were removed from the wells and the wells left unplugged and improperly abandoned. Subsequent activities, including building construction, buried most of these abandoned wells. This resulted in a complex problem that cannot be easily corrected.

2) Based on known problem areas and discussions with local residents, the NETL study was limited to an area bounded to the north by the City of McKeesport, to the east by Walnut Street, to the south by the Boston Bridge, and to the west by the Youghiogheny River. Thus, the study area was defined by where there were known or suspected problems. This does not mean that all of the structures outside the study area are safe from stray methane problems, since many wells were drilled outside of the study area. For example, gas emissions have not been reported for the area of Versailles Borough east of Walnut Street. During the gas boom, this area was more rural and had larger plots of land with fewer wells, and many of those wells were outside the productive area of the Speechley sandstone and never produced gas, but some did.

3) Previous gas leak investigations by other parties resulted in vents being installed over areas where gas concentrations were high at the surface. Some of these vents were over actual abandoned wells; most were not.

4) Most of the vents show no evidence of a gas flow, at least measurable at a minimum rate of 0.5 $ft^3$/hr. Of those connected to wells, only a couple of vents are actually producing gas flows in excess of 0.5 $ft^3$/hr. Total gas production from all vents and wells prior to clean-out of any well was approximately 70 $ft^3$/hr, with the majority of this production (50 $ft^3$/hr) coming from a single well on the 4700 block of Second Street.

5) Many of the vents have had little or no maintenance since installation and some have been removed. Some with top-mounted rotating ventilators showed evidence of severe rust and mechanical degradation. Some wells had bird or bee nests that were inhibiting gas ventilation.

6) The Murrysville Anticline cresting under the Borough combined with the open wellbores, appear to be a major contributor to the current gas leakage problem. Gas has migrated along the limbs of the anticline towards the structurally highest point. Normally this gas would remain in the higher permeability formations due to overlying lower permeability

formations and the weight of the overlying geologic formations. However, since these formations are breached by the open well bores, the gas is allowed to migrate to the surface soils and atmosphere. During dry weather conditions, the gas can leak through the surface soil and into the atmosphere. During wet weather, the moisture fills the rock fractures and soil pores, impeding the vertical gas migration and temporarily re-directing the gas horizontally in the lower part of the soil horizon or in more permeable rock formations. This lateral migration can lead to gas entering building foundations.

7) Gas sampling indicates the gas is most likely a combination of deeper Devonian formation gas and minor amounts of shallower coal bed methane. Vertical gas migration from these formations is through the old abandoned wellbores.

8) Down-hole video surveys showed shallower formations were providing lateral gas migration pathways, at least in the two surveyed wells. The primary lateral migration pathway in the Walnut Street wellbore is through the Upper Freeport coal seam and then up the old wellbore to the surface. The Buffalo sandstone is the lateral migration pathway in the Borough garage wellbore. Gas in the near-surface Buffalo sandstone appears to migrate up and out of the wellbore to the surface where part of the well casing is still present, creating a single point source for stray gas. However, where the surface casing is missing, gas can migrate a distance away from the wellbore in the surface soils.

9) Magnetometry was used to locate 52 subsurface anomalies that are believed to be abandoned wells. Of these 52 anomalies, 14 anomalies were found to be leaking methane. Originally, two sections of the Borough were thought to be the only problem areas for methane gas leakage – the 4300 block of Walnut Street and Third Street and the 4700 and 4800 blocks of Penn Way and Second Street. The 14 anomalies that were leaking methane were between these two sections.

10) Historical pictures showed old drilling derrick locations. Magnetometer and Apogee methane detection surveys over these areas indicated that old wellbores are the primary gas pathway to the surface.

11) Both old wells that were opened to determine the methane source had wood, bricks, rocks, and other materials thrown into the wells over time. Cleaning out this debris added significantly to the drilling costs and time required to clean the wells. The lack of wellbore casing means that the geologic formations have been exposed to the well water for a long time, making them less stable. The instability of these formations, especially shale formations, also added to the drilling costs. It was found that a cable tool rig working without the addition of water to the wellbore worked better than a rotary rig using water as a drilling fluid.

12) Hydrogen sulfide ($H_2S$) was found to be present in minor amounts in two vents along Second Street prior to opening the two old abandoned wells. In addition, $H_2S$ levels exceeding the 100 ppm National Institute of Safety and Health (NIOSH) Immediately Dangerous to Life and Health (IDLH) level were measured within one well about a month after the well was opened and cleaned for the video camera work. The well was

shut in (all venting terminated), appropriate authorities were notified, and a $H_2S$ removal cartridge was installed. Due to the low well flow rate (6.5 $ft^3$/hr) and atmospheric dilution, $H_2S$ ambient levels were below measurable limits within a couple feet of the well. Trained personnel with monitoring and safety equipment were on-site during all sampling and work completed on the well after the initial high reading. Wellbore $H_2S$ levels dropped to 104 ppm within four days of installing the $H_2S$ removal cartridge and reopening the well, and within 4 months, had dropped to undetectable levels in the wellbore. The $H_2S$ ambient levels were virtually zero (below measurable limits) within a couple feet of the well throughout all of this time.

13) Methane gas problems associated with the well at 4307 Third Street appear to be related to gas coming up the back (annulus) of the smaller diameter casing left in the hole at a depth of 44 feet. At this point, the smaller casing is separated from the larger (6-inch) surface casing, allowing gas to migrate into the surrounding permeable geologic formations. The well currently has an electric blower attached to the vent, which helps move gas up the well and out to the atmosphere; however, gas could still be leaking into surrounding, more permeable, geologic formations.

14) Gas was visibly seen emanating from the Upper Freeport coal seam in the Walnut Street well. Lack of gas flow or pressure on the annulus side of the installed casing suggests that the gas migration pathway is limited solely to the Upper Freeport coal in this well and that the gas has not migrated to any of the overlying formations.

15) Slightly more than an order-of-magnitude increase (10 to 120 $ft^3$/hr) in gas volume was noticed by reducing the Upper Freeport coal hydrostatic pressure by approximately 75 psi at the Walnut Street well.

16) The Methane Buster™ was found to increase the volume of gas that could be extracted, but required lowering the water level in the well to reduce the hydrostatic pressure. Costs associated with treating and/or hauling sodium-rich water would be expensive, especially since there does not appear to be marketable amounts of gas left in the coal seam.

17) Gas volume decreased from 50 to 35 $ft^3$/hr at the 4805 Second Street well while water was being pumped and the Methane Buster™ was being tested at the Walnut Street well. This would suggest interconnectivity across the two areas and that increasing methane gas extraction from a point source may pull the gas from a larger area of influence.

18) The absence of gas bubbles below the Buffalo sandstone in the down-hole video survey in the Borough garage well indicated that gas was migrating vertically up nearby wellbores and moving laterally in the near-surface Buffalo sandstone in the Borough garage well. The inability to seal off gas from the annulus while running tubing in the well confirmed that the gas was entering the wellbore via the Buffalo sandstone. Vertical migration via the old wellbores combined with possible horizontal stray gas migration in the porous soils during wet conditions may be contributing to the widespread methane gas problems in the 4700 and 4800 blocks of Penn Way and Second Street.

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# 5.0 Mitigation Options

A remedial action plan is presented to protect public health and safety. Costs are based on labor and material data from "Facilities Construction Cost Data" by R. S. Means (2005), using standard engineering practices, and are broken down in a little more detail in Attachment I. Costs were converted to 2007 values by increasing line items by 10%. Due to the numerous uncertainties and unknowns, an attempt was made to provide costs that would allow for contingencies. The costs are considered to be reasonable engineering estimates and should provide a sound basis for decision making. However, more detailed costs will need to be developed on a case-by-case basis. It should also be noted that no single remediation option will mitigate all of the stray gas problems within the Versailles Borough. A remedy that works for one building or area of the Borough may not work at others. The final remedy will undoubtedly require implementation of several of these remedial options.

## 5.1 Short Term Remediation Strategy

### 5.1.1 Immediate inspection, repair, or replacement of existing vents suspected of being compromised and allowing gas to migrate from the well into the subsurface

Several existing vents have not been maintained since installation. Bird's nests and/or insects have obstructed some vents reducing their flow efficiency. Other vents have deteriorating parts, have been removed by the owner, provide an ineffective seal with the ground, or are not of sufficient height to ensure gas is venting above adjacent structures.

Vents that are suspected to be compromised and leaking gas should be evaluated and repaired immediately by qualified personnel. Vents suspected to be ineffective should be assessed by conducting monitoring at the well vent and by conducting a soil gas survey in an area radial of the vent with a properly calibrated combustible gas indicator. When possible, soil gas surveys should be conducted during approaching barometric low pressure systems. Soil gas surveys for certain locations may be required on more than one occasion. Vents that reveal areas proximal to the vent where the soil gas contains sustained concentrations of combustible gas in the subsurface should be prioritized for repair or replacement.

Properly constructed vents should incorporate the following:

- An effective *seal with the old wellbore, if the location is known to be over an abandoned well*. In cases where wellbore casing does not exist or integrity is compromised, new casing should be installed (on a packer system inside of old casing or an open hole, if necessary) to ensure gas is not leaking from the wellbore into the soil or near surface permeable formations.
- *Can be entered or easily removed for future testing or remedial action*. The vent should be installed to provide an effective seal with the ground and be structurally stable, but should not be cemented into the ground. A non-permanent sealing material such as bentonite should be used to ensure good vent to ground seal.

- *Is equipped with screening to keep out insects and birds*. Screening materials should have a small enough grid to keep out insects such as bees that construct nests and of a material that will not rust or be affected by venting gas or climatic elements.
- *Is made of materials that would not be easily attacked by the stray gas or climatic elements*, i.e. schedule 40 or 80 PVC pipe.
- *Vents should be equipped with stainless steel wind-driven turbines to facilitate gas flow from the subsurface.*
- *Some vents may have to be vented more actively by mechanical fans.*
- *Is aesthetically pleasing to the homeowner and the neighborhood.* When possible, vents should be installed to complement the structure on the property. An example would be a vent securely attached to the structure and designed to follow the roof drains with the vent turbine above the roof line.

Cost per vent can range from a few tens of dollars to several thousand dollars, depending on level of inspection and extent of repairs, replacement, and monitoring costs.

#### 5.1.2 Install ventilation trenches in areas where stray hydrocarbon gas has been detected in the soils within 5-10 feet of a structure

Stray hydrocarbon gas within 3 feet of a structure typically results in a notice from the natural gas utility company that gas service will be terminated due to the risk of gas entering the structure. Ventilation trenches are typically 2-4 feet wide and installed to a depth of 3-4 feet below grade. The trenches are lined with 2B gravel with 4-6 inch diameter perforated PVC pipe placed over the length of the trench. The pipe is placed in the trench with the two sets of perforations face down at roughly 45 degree angles. One end of the PVC pipe in the trench is fitted with a vertical vent, no less than 10 feet in height. The vent should be fitted with a stainless steel wind driven turbine. The other end of the pipe in the trench is fitted with a 90º PVC elbow and capped to be flush with the surface. This section can be fitted with a powered fan if improvement in ventilation is required. The trench may be designed around the entire perimeter of a structure or along one side. The length of the trench would be site specific and dependent on the distribution of stray gas in the subsurface, but an average trench, for one side of a building, will probably cost $10,000 or less. Ongoing monitoring in the vicinity of the ventilation trench will be required for some period of time to determine its effectiveness.

#### 5.1.3 Install Sub-slab pressurization (SSP) systems in structures known to contain stray hydrocarbon gas

SSP systems create a positive pressure clean air buffer below the structure and effectively counteract the low-pressure field created naturally by the structure. These systems are recommended for structures over conventional Sub-slab depressurization systems (SSD) in areas where the concentration and volume of gas is significant or unknown. SSD systems create a negative pressure below the slab drawing more gas towards the structure and through the vent. They are very effective to mitigate low concentrations and volumes of stray gas. However, in areas where the concentration and volume of stray gas is significant, these systems can be overcome resulting in contaminated air entering the structure.

A mechanical fan that directs outside air through vertical vent(s) into the sub-slab material powers the SSP systems. These systems are only effective if the material below the slab is permeable to evenly distribute the air to the area below the slab. In materials that are not sufficiently permeable, horizontal extension(s) of the vertical vent and replacement of the impermeable material with permeable gravel (2B or 1B) may be necessary to improve system performance. SSP systems should be designed with properly sized mechanical fans to create a pressure field for the area below the footprint of the structure and incorporate a manometer to record pressure created by operation of the systems. Prior to installation of the SSP systems, construction gaps and cracks in the concrete floor must be repaired with hydraulic or non-shrinking cement to prevent short-circuiting of the air.

Installation of SSP systems should be conducted by experienced and qualified personnel in accordance with general provisions provided in USEPA 1993b, ASTM 2002b, new residential construction (USEPA 1994a), and large buildings (USEPA 1994b). The Interstate Technical Regulatory Council (ITRC) Technical Guidance “Vapor Intrusion Pathway: A Practical Guidance” may also be a useful resource on the installation of SSP systems. The general recommendations of these guidance documents should be followed for mitigation of vapor intrusion, with appropriate modifications for site-specific conditions and regulatory or building code permit requirements. The average cost per system is estimated at $3,000.

### 5.1.4 Installation of methane alarms in buildings within the study area

Methane alarms are recommended for installation in all structures at risk in the study area. At risk structures are defined as those where known or suspected abandoned gas wells exist within 25 feet of the structure or in structures where stray hydrocarbon gas has been documented in the soil gas within 25 feet of the structure.

Methane specific alarms utilizing remote sensors and separate control boxes with audible and visual alarms are recommended for installation. These cost $250-300 a piece (excluding the cost of installation). The remote sensors should be installed near the ceiling in the lowest level of the structure and the control box should be installed in the main area of the structure where the audible and visual alarms can be easily recognized. The units should alarm at concentrations between 10% and 20% of the lower explosive limit, 5% by volume for methane. The alarms should be installed by a qualified electrician.

### 5.1.5 Vent detected methane gas anomalies from the Apogee gas-detection survey

In addition to the two wells that were opened and vented as part of this study, 12 other anomalies were detected that revealed methane gas leakage. Locations of these 12 anomalies are given in Table 3. At a minimum, these 12 anomalies should be investigated to determine if excavation and vent installation is required to mitigate stray gas in the soils. All locations should be further evaluated to determine if more active venting is required.

Down-hole work to clean out and improve venting of a wellbore may be required at some locations. Depending on condition of the well, this work may be very involved and expensive. Down-hole electric logs and video camera work followed by repair and/or replacement of casing may be required. However, at many sites, the level of effort required will be relatively minor; the average cost, per vent, is estimated at $1,300, assuming no wellbore cleaning, down-hole video, or geophysical logging are required.

### 5.1.6 Vent Existing Wells

Proper well venting will reduce the incidence of stray gas migration in the Borough. Many abandoned and improperly plugged wells were found during this investigation using the magnetometer and Apogee surveys. Some were found to be leaking below the ground surface, thus allowing gas to migrate horizontally within the soil to structural foundations. Two options are presented: a non-drilling option and a drill and clean option. Both options assume the gas is leaking through the casing in the old well and not from the annulus (space between the casing and borehole) of any casing remaining in the ground.

#### 5.1.6.1 Well Venting - Non-Drilling Option

In the non-drilling option, the well leaking gas is uncovered by excavating the area around the well. Depending on the depth to the top of the well, excavation may be accomplished by hand or may require power equipment. Once exposed, a passive or blower-equipped vent would be installed to the existing well casing. Damaged or missing surface conductor casing should be replaced, newly installed, or smaller casing run on a packer to eliminate gas migration into the surrounding soil and/or near-surface permeable formations. The non-drilling option is similar to what is currently being done to the wells within the Borough; the estimated average cost is $1,300 per well. This approach allows the gas to escape, reducing wellbore pressure. The more wells that can be opened this way, the less likelihood the gas will migrate horizontally. However, since the wellbore may have partial blockage at depth or be leaking through corroded holes or the annulus of the remaining casing, this method does not ensure that all of the gas will be vented and gas could still migrate into structures. Finally, it is likely that additional magnetic and Apogee surveys may be required, particularly after major precipitation events, since it is believed that saturated soils prevent vertical gas migration and forces the migration path back to the well bore. A monitoring plan should be established to test for gas leaking around the completed vent and the vent checked periodically for stray gas leakage around the vent or in the nearby soil. Vent construction should be in accordance with the description in the preceding Immediate Recommendations section.

*Pros:*

- Localized area of work
- Relatively inexpensive
- Only required at known or found wells and/or methane gas leaks

*Cons:*

- Does not get missed or hidden sites
- Does not ensure that gas leaking up outside of casing can be captured from subsurface leaking casing
- Does not ensure gas will not continue to migrate towards a structure
- No methane utilization

#### 5.1.6.2 Well Venting - Drilling Option

The drilling option is similar to the non-drilling option except that existing gas emitting wells would be cleaned and drilled out to below the gas-producing formation. Some restrictions, other than cost, may limit the applicability of this option, such as whether or not it is possible to place a drilling rig at a narrowly defined site due to the proximity of buildings and power lines. Under this option, the best scenario would be to drill out the existing well, set casing to ensure that gas does not leak into geologically higher formations, and then vent the well. Costs for this option are more expensive initially for the drill rig, casing, and open-hole packer assembly or grouting material. Debris has been thrown down several of these wellbores over time. Removal of this debris is time consuming and expensive because of the varied nature of the materials thrown in the wells. The two wells cleaned out as part of this project had formation bridges across the wellbore, old bricks, pieces of wood, metal window parts, cement, as well as wellbore integrity problems due to prolonged exposure to water. On average, this approach is estimated to cost about $30,000 per well, assuming an average well clean-out depth of 300 feet. This assumes the use of a cable tool rig without the addition of water to the wellbore, rather than a rotary rig and water as a drilling fluid. This approach should be more efficient if there is debris in the well and is less likely to stimulate the generation of $H_2S$.

The gas can be directly diverted to the atmosphere, or preferably, for some beneficial usage. There is a much lower probability that the gas will migrate towards a structure than in the non-drilling option because the casing will prevent the methane from entering the shallower permeable formations or the soil zone. A monitoring plan should be established, both around the vent and inside any adjacent structures, to determine if the well vent is effective. Once venting effectiveness has been established, monitoring can be reduced to periodic sampling of the building interior and around the vent. Vent construction should be in accordance with the description in the preceding Immediate Recommendations section.

*Pros:*

- Localized area of work
- Only required at known leaks
- Better chance of capturing methane than not cleaning and casing wellbore

*Cons:*

- Expensive
- Unsure of obstacles in wellbore
- Not going to have access or be able to locate all wells

### 5.1.7 Borough Should Consider Passing a New Construction Ordinance

Any site for new construction that creates a seal at the surface (including above ground swimming pools) should be investigated for the presence of a wellbore and methane gas prior to construction. Gas venting should be part of the construction plan as well as an approved monitoring plan to ensure stray gas is not trapped under the structure. The Borough Council should consider passing an ordinance to ensure gas does not accumulate under any new construction within the Borough. Example ordinances from localities in California with similar problems and proposed venting techniques are given in the Appendix section of this report.

#### 5.1.8 Borough Should Consider Acquiring Portable Methane Detection Devices for Testing Gas Content in Structures and Vent Integrity

Several portable rechargeable methane detection meters are available as off the shelf instruments. The instrument should have the methane percentage readout (preferably digital), an alarm that sounds when the level reaches near explosive levels (5 – 15% by volume for methane), and equipped with an intake wand that can be extend out to arms length to protect the inspector a distance away from the gas source. Since hydrogen sulfide ($H_2S$) was found at a few wells, it may be advisable to specify $H_2S$ sensors in the meters. Some combination instruments read the concentration of methane ($CH_4$), $H_2S$, carbon monoxide (CO), and oxygen ($O_2$) as well as sounding an alarm when concentrations exceed preset levels. Because most of the better instruments require periodic calibration and recharging between uses, the Borough should consider acquiring two or more instruments to guarantee an instrument is operational and calibrated when needed. Borough personnel will require training on how to calibrate and maintain the meters.

### 5.2 Long Term Remediation Strategy

Two possible remediation options are discussed to assist the Borough Council and residents in determining future actions and funding requirements. These options require additional analyses and pre-design pilot scale testing.

#### 5.2.1 Producing Gas from the Shallow Subsurface in the 4700 and 4800 Blocks of Penn Way

Some volume of methane gas appears to have migrated into the Buffalo sandstone through open wellbores and corroded surface conductor casings in the area within the 4700 and 4800 blocks of Penn Way and Second Street. Several gas vents are located in this area. The area has been an area of increasing methane gas leaks onto property and into structures. A long term option for this portion of the study area would focus on attempting to drain the gas from the Buffalo sandstone, but additional research is needed before it can be determined if this option is feasible.

##### 5.2.1.1 Summary of General Approach

An iterative drilling approach would be pursued in this remedial option; details are presented below. This approach (degasification) would focus initially on addressing the leakage in the areas with the highest stray gas concentrations.

Initially, three vertical wells would be drilled to the bottom of the Buffalo sandstone coupled with a vacuum system in an attempt to drain gas without having to treat water. During this initial drilling, water will be sampled from various depths in all three wells. All wells will be cored. The groundwater samples will be analyzed for various ions and anions, and results will be used to estimate potential water treatment requirements. The core samples will be tested for hardness, strength, permeability, and porosity.

If the initial drilling program is unsuccessful, pump and treat operations will be required to lower the water table and release the methane. In this approach, hydrological testing (e.g., pumping tests) in the three vertical wells would be required to determine the pumping (groundwater recharge) rate to maintain optimal gas flow, as well as for determining the required treatment rate and water handling needs (e.g., pump size and piping). Based on the quality of the water and regulatory requirements, decisions will be made on water handling and/or treatment.

#### 5.2.1.2 Vertical Well Drilling Details

Drilling three vertical wells is proposed to determine if the gas can be extracted from the sandstone without having to produce or treat formation water in the Buffalo sandstone. Three vertical wells would be drilled to the top of the Buffalo sandstone (≈ 20 feet from the surface), casing run, and casing set in place using either an open-hole packer or a bentonite grout seal. The sandstone would then be drilled open hole to the base of the sandstone (≈ 80 feet from the surface). The estimated total cost for this drilling is $20,000. The wells would be located along the First Street side of Penn Way. The first well should be drilled across from the existing Borough Garage well, the second near the intersection of Penn Way and Wampler Street, and the third near the intersection of Penn Way and Larch Street. Soil gas samples would be taken of yards in the area using a permanent sampling grid system prior to and during testing to determine if gas levels were being lowered in the area. Gas flow rates from existing vents would also be monitored to determine if this approach was lowering emission rates over a large area. Soil gas sampling stations would be developed and surveyed using a geographical positional station, wells would be drilled and interconnected through a manifold, and a Methane Buster™ or the suction side of a natural gas compressor connected to the well manifold system. Renting and fuel for a Methane Buster™ would cost about $10,000 for 3 months. Gas production and the effects of producing gas from the Buffalo sandstone on nearby vented wells and from additional soil gas surveys would be monitored during these 3 months. The cost of engineering the study and the monitoring is estimated at $30,000.

*Pros:*

- Could remove leaking gas from a large area from a few single points
- Collected gas could be used by the Borough to offset costs
- Requires shallow, relatively inexpensive wells

*Cons:*

- Could pull gas from other areas and affect wells that have not been located or are under existing structures
- Could require a long-term commitment of funds and equipment maintenance

#### 5.2.1.3 Pre-design testing

If the initial drilling is successful, either a smaller version of the Methane Buster™ or a natural gas compressor system would be installed. Soil gas and vented well flow measurement monitoring would have to continue for six additional months. However, if the initial phase of work is not successful, hydrological testing (e.g., pumping tests) in the three vertical wells will be required to determine the pumping (groundwater recharge) rate required to maintain a maximum gas flow, as well as for determining the required treatment rate and water handling needs (e.g., pump size and piping). A submersible pump would have to be installed in each well, and a small natural gas compressor, gas/water separator, and associated piping, would have to be installed. Neglecting the costs of handling and/or treating the water, which cannot be estimated at this time, the total costs, assuming a 1.5 horse power submersible pump in each well with 1.5-inch tubing and a safety shut-off, would total about $65,500.

*Pros:*

- Previous production tests with the Methane Buster™ have shown that lowering the water level has enhanced gas production and reduced methane gas flow rates from nearby vented wells

*Cons:*

- Additional equipment operating and maintenance expenses

#### 5.2.1.4 Horizontal Well Drilling Details

If the vertical wells are successful or water can be successfully removed without prolonged or expensive treatment, and it is viable to appropriately place the wellbore without causing surface disturbance, the shallow producing formations could be directionally drilled to create a horizontal, tree-branch style pattern under Versailles Borough. The initial area targeted would be the Penn Way – Second Street area. Drilling would be similar to running utilities under a roadway or other obstruction. Drilling would start in the floodplain area between the railroad tracks and the Youghiogheny River. Drilling would be steered using directional drilling by utilizing a sounding beacon and/or logging while drilling. This technology should extend the effectiveness of the approach at a relatively low additional cost.

An appropriate horizontal well would cost between $100,000 – 200,000, depending on number of horizontal wells (limbs) drilled off of the main horizontal well, rate of penetration based on sandstone hardness, amount of produced water while drilling, and ability to remain in the formation while drilling. Monitoring would have to continue for at least a year, and would cost about $100,000 more.

### 5.2.2 Put Existing Producing Wells and Vents on a Vacuum System

Another approach would be to install a pipeline system within the study area to tie all of the producing wells and vents into a central collection system. The system would be connected to a vacuum system and the gas would utilized by the Borough, connected to a local gas distribution pipeline (if there was sufficient gas quantity and quality), flared, or vented to the atmosphere in an area away from the residences or businesses. Monitoring would be required to ensure that stray hydrocarbon gas was not entering structures while being drawn from areas within the Borough. It is estimated that constructing such a system would cost about $2,500,000.

It is doubtful that sufficient quantities of stray hydrocarbon gas can be produced to provide sales to local pipelines or distribution systems, even if multiple wells are combined. Wellhead gas pressure readings taken at the Borough garage well was less than 5 psi and the combined well and vent production within the study area was less than 100 $ft^3$/hr (2.4 Mcf/day). There may, however, be sufficient gas volume and flow rates for use within the Borough. This would require piping the gas to the utilization end point and combining the gas from several wells. However, if the gas is used for some purpose other than pipeline sales, the gas must be continuously used. If the gas is not used continuously, it is the same as shutting in the well (or group of wells), allowing the subsurface pressure to rebuild, and forcing the gas to migrate to another location (including buildings) through the old wellbores. Some possible gas usage suggestions include:

- An eternal flame burning at the war memorial adjacent to the Borough municipal building could provide a continuous use for the gas.

- Gas-operated street lights along Walnut Street (or some other location) would not only add lighting, but beauty and charm to the area while reducing the methane gas problem.

- Run a dedicated electric generator to supply electricity to one or more Borough buildings (i.e., municipal building, Borough garage, fire station).

- A supply for natural gas-operated vehicles or equipment.

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# 6.0 Glossary

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| Annulus: | With respect to a well, the space between one well casing and another casing or the space between the well casing and the wellbore. |
| Anticline: | A folding of rock strata; both sides incline downward from a median line or axis. |
| Casing: | Steel pipe or tubing used in gas and oil wells to protect the wellbore and associated geologic strata from the gas or oil production. |
| Cross-section: | A profile portraying an interpretation of a vertical section of the earth. |
| Formation: | A body of rocks possessing certain distinct lithologic features that indicate genetic relationships that are classed as a unit for geologic mapping. |
| Geophyscial: | The exploration of an area or the subsurface with respect to its structure, composition, and development. |
| Lithologic: | Pertaining to the mineral composition and structure of rocks. |
| Magnetometer: | An instrument for measuring the intensity of the earth's magnetic field. |
| Manometer: | An instrument used to measure the pressure of liquids and gases. |
| Permeability: | The capacity of a rock for transmitting fluids. Degree of permeability depends on the size and shape of the pores (open spaces) within the rock, the size and shape of the interconnectivity of the pores, and the extent of pore interconnectivity. |
| Pore: | A space (interstice or void) in a rock or soil not occupied by solid mineral matter. |
| Porosity: | The ratio, expressed as a percentage, of the volume of the pores or interstices of a rock to its total mass. |
| Sandstone: | A rock composed of sand, usually quartz, cemented together silica, calcium carbonate, iron oxide, and clay. |
| Vertical Exaggeration: | In a geologic cross-section, the increase in vertical relief as compared to the horizontal distance. |
| Wellhead: | The valves and fittings above the ground on a well. |

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# 8.0 Appendices

**A. Los Angeles, California Municipal Code "Ordinance No. 175790"**

**B. Los Angeles Department of Building and Safety Information Bulletin "Methane Hazard Mitigation Standard Plan: Simplified Method for Small Additions"**

**C. Huntington Beach, California Municipal Code "Chapter 17.04 of the Building Code"**

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# Appendix A

## ORDINANCE NO. 175790

An ordinance amending Section 91.106.4.1 and Division 71 of Article 1, Chapter IX of the Los Angeles Municipal Code to establish citywide methane mitigation requirements and include more current construction standards to control methane intrusion into buildings.

**WHEREAS,** there was a fire in the Fairfax Area of the City of Los Angeles in 1985, due to high volume of methane gas seepage through cracks in the concrete floor of a building;

**WHEREAS,** the City of Los Angeles adopted an Ordinance, (Ord. No. 161,552, Eff. 8-31-86) which required mitigation for methane gas intrusion into buildings located in the Fairfax area of Los Angeles;

**WHEREAS**, methane gas which percolates from subsurface geological formations to the atmosphere is a natural phenomenon;

**WHEREAS,** in 1999, large pockets of methane gas in subsurface geological formations were discovered at the Playa Vista project area of West Los Angeles;

**WHEREAS,** in 2001, new methane mitigating systems were developed and used in the Playa Vista Project;

**WHEREAS,** in Council File No. 01-1305, the City Council directed the City=s Departments of Building and Safety, Engineering, and Planning, as well as, the Chief Legislative Analyst and Office of Administrative and Research Services, to form a work group and recommend uniform safety requirements regarding methane, for all future development throughout the City;

**WHEREAS,** a study by the work group was conducted regarding areas throughout the City of Los Angeles to identify areas where subsurface methane gas may be found;

**WHEREAS,** from the information and data provided by the Division of Oil, Gas and Geothermal Resources, Department of Conservation, State of California, City of Los Angeles Department of Environmental Affairs, Department of Building and Safety and the Fire Department a map was plotted by the Department of Public Works to show other areas within the City of Los Angeles, where there exists a possible potential hazard of methane gas;

**WHEREAS,** modern construction standards were successfully used as methane mitigation systems for many projects in Playa Vista;

**WHEREAS,** the work group utilized the research and knowledge gained through the development of the Playa Vista methane mitigation systems;

**WHEREAS,** many of the modern construction standards to mitigate potential hazard of methane gas intrusion into building were incorporated into the Los Angeles Municipal Code as more restrictive provisions than found in the 2001 edition of the California Building Code based on local geological conditions;

**NOW, THEREFORE,**

**THE PEOPLE OF THE CITY OF LOS ANGELES
DO ORDAIN AS FOLLOWS:**

Section 1. Exception 6 of Section 91.106.4.1 of the Los Angeles Municipal Code is amended to read:

> **6.** The Department shall have the authority to withhold permits on projects located within a Methane Zone or Methane Buffer Zone established under Sections 91.7101 *et seq.* of this Code. Permits may be issued upon submittal of detailed plans that show adequate protection against flammable gas incursion by providing the installation of suitable methane mitigation systems.

Section 2. Division 71 of Article 1, Chapter IX of the Los Angeles Municipal Code is amended to read:

## DIVISION 71
## METHANE SEEPAGE REGULATIONS

### SEC. 91.7101. PURPOSE.

This division sets forth the minimum requirements of the City of Los Angeles for control of methane intrusion emanating from geologic formations. The requirements do not regulate flammable vapor that may originate in and propagate from other sources, which include, but are not limited to, ruptured hazardous material transmission lines, underground atmospheric tanks, or similar installations.

## SEC. 91.7102. DEFINITIONS.

For the purpose of this division, certain words and phrases are defined as follows:

**Alarm System** shall mean a group of interacting elements consisting of components and circuits arranged to monitor and annunciate the status of gas concentration levels or supervisory signal-initiating devices and to initiate the appropriate response to those signals.

**Buildings with Raised Floor Construction** shall mean a building with the bottom of the floor system raised above grade where the clearance for each of the following items shall be at least: 12 inches for the girder, 18 inches for the floor joist and 24 inches for the structural floors.

**Cable or Conduit Seal Fitting** shall mean an approved fitting provided in a cable or conduit system to prevent the passage of gases, vapors, or flames through electrical cable or conduit.

**Design Methane Concentration** shall mean the highest concentration of methane gas found during site testing.

**Design Methane Pressure** shall mean the highest pressure of methane gas found during site testing.

**De-watering System** shall mean a permanent water removal system, consisting of perforated pipes, gravel, sump pumps and pits, designed to permanently maintain the ground water level one foot below the sub-slab vent system.

**Gas Detection System** shall mean one or more electrical devices that measure the methane gas concentration and communicate the information to the occupants, building management, central station or alarm company with audible or visual signals.

**Gravel Blanket** shall mean a layer of gravel, sand, or approved material designed to transmit gas to the vent riser without obstructing the venting system.

**Impervious Membrane** shall mean a continuous gas barrier made of material approved by the Department and installed beneath a building for the purpose of impeding methane migration to the interior of the building.

**Mechanical Extraction System** shall mean a system operated by a machine which is designed to remove methane gas from below the impervious membrane through the use of fans, blowers, or other powered devices.

**Mechanical Ventilation** shall mean a fan, blower or other similar group of interacting elements operated by a machine within the building, which introduce and/or remove air from an enclosed space.

**Narrow Building** shall mean a building that has a width less than 50 feet, a footprint of less than 50,000 square feet and having a minimum 2-foot wide landscaped area immediately adjacent to the exterior wall for at least 50 percent of the perimeter of the building.

**Oil Well** shall mean a deep hole or shaft sunk into the earth for the exploration of oil or gas; or which is on lands producing or reasonably presumed to contain oil or gas; or which is drilled for the purpose of injecting fluids or gas for stimulating oil recovery, re-pressurizing or pressure maintenance of oil or gas, or disposing of waste fluids from an oil or gas field.

**Perforated Horizontal Pipe** shall mean an approved pipe which contains a series of small holes or narrow openings placed equidistant along the length of the approved pipe, which is placed horizontally beneath the foundation of a building, for the purpose of venting accumulated methane gas and preventing the development of elevated gas pressures, or for drainage of ground water to an approved location.

**PPMV** shall mean Parts per Million by Volume.

**Pressure Sensor** shall mean a device that measures and communicates surrounding gas pressure to an alarm or control system.

**Single Station Gas Detector** shall mean a device consisting of electrical components capable of measuring methane gas concentration and initiating an alarm.

**Trench Dam** shall mean an approved subsurface barrier installed within a furrow or ditch adjacent to the foundation of a building, for the purpose of preventing the migration of methane gas beneath that foundation.

**Unobstructed Opening** shall mean a permanent clearing or gap in the walls, floors or roof-ceiling assemblies without windows, doors, skylights or other solid barriers that may restrict the flow of air.

**Vent Riser** shall mean an approved pipe which is placed vertically with joints and fittings connected to Perforated Horizontal Pipes to convey and discharge the gas to the atmosphere.

**SEC. 91.7103. GENERAL METHANE MITIGATION REQUIREMENTS.**

All new buildings and paved areas located in a Methane Zone or Methane Buffer Zone shall comply with these requirements and the Methane Mitigation Standards established by the Superintendent of Building. The Methane Mitigation Standards provide information describing the installation procedures, design parameters and test protocols for the methane gas mitigation system, which are not set forth in the provisions of this division.

Boundaries of the Methane Zones and Methane Buffer Zones are shown on the AMethane and Methane Buffer Zones Map@ designated as Map number A-20960, dated September 21, 2003, which is attached to Council File No. 01-1305.

**SEC. 91.7104. GENERAL METHANE REQUIREMENTS.**

**91.7104.1. Site Testing.** Site testing of subsurface geological formations shall be conducted in accordance with the Methane Mitigation Standards. The site testing shall be conducted under the supervision of a licensed Architect or registered Engineer or Geologist and shall be performed by a testing agency approved by the Department.

The licensed Architect, registered Engineer or Geologist shall indicate in a report to the Department, the testing procedure, the testing instruments used to measure the concentration and pressure of the methane gas. The measurements of the concentration and pressure of the methane gas shall be used to determine the Design Methane Concentration and the Design Methane Pressure. The Design Methane Concentration and the Design Methane Pressure shall determine the Site Design Level of Table 71.

**EXCEPTION:** Site testing is not required for buildings designed to the requirements of Site Design Level V as described in Table 71, or for buildings designed using the exceptions set forth in Sections 91.7104.3.2 or 91.7104.3.3.

**91.7104.2. Methane Mitigation Systems.** All buildings located in the Methane Zone and Methane Buffer Zone shall provide a methane mitigation system as required by Table 71 based on the appropriate Site Design Level. The Superintendent of Building may approve an equivalent methane mitigation system designed by an Architect, Engineer or Geologist.

Table 71 prescribes the minimum methane mitigation systems, such as, the passive, active and miscellaneous systems, depending on the concentration and pressure of the methane present at the site. Each component of the passive, active and miscellaneous systems shall be constructed of an approved material and shall be installed in accordance with the Methane Mitigation Standards.

**91.7104.2.1. Passive System.** The passive system is a methane mitigation system installed beneath or near the building. The components of the passive system may consist of a de-watering system, the sub-slab vent system, and impervious membrane. The sub-slab vent system shall consist of Perforated Horizontal Pipes, Vent Risers, and Gravel Blankets for the purpose of collecting and conveying methane from the soil underneath the building to the atmosphere.

**91.7104.2.1.1. De-watering System.** The de-watering system is used to lower the ground water table to a level more than 12 inches below the bottom of the Perforated Horizontal Pipes. The de-watering system shall conduct ground water to an approved location.

**91.7104.2.2. Active System.** The components of the active system shall consist of one or more of the following, sub-slab system, gas detection system, mechanical ventilation, alarm system and control panel. All components shall be constructed of an approved material, installed in accordance with the Methane Mitigation Standards.

**91.7104.2.3. Miscellaneous System.** The components of the miscellaneous system may consist of Trench Dam, Cable or Conduit Seal Fitting, or Additional Vent Risers. The component of the miscellaneous system shall be a material approved by the Department and shall be installed in accordance with the Methane Mitigation Standards.

**91.7104.3. Exceptions to Table 71.** The provisions of this section are exceptions to the construction requirements of Table 71.

**91.7104.3.1. Narrow Buildings.** Narrow Buildings may substitute Pressure Sensors below the Impervious Membrane in lieu of the Gas Detection System and Mechanical Ventilation, if the installation of the Pressure Sensors below the Impervious Membrane is not required per Table 71 and the Narrow Building is constructed with a minimum two feet wide landscaped area covering at least 50 percent of the ground immediately adjacent to the exterior building walls.

**91.7104.3.2. Buildings with Raised Floor Construction.** If a Building with Raised Floor Construction has underfloor ventilation construction in accordance with the standards below, then the utilities shall be installed with Trench Dams and Cable or Conduit Seal Fittings and a four inch thick gravel blanket shall be installed under and around the elevator pits. Underfloor ventilation shall be provided by an approved mechanical ventilation system capable of exhausting underfloor air an equivalent of every 20 minutes, or by openings in the underfloor area complying with the following:

**A.** The top of the openings shall be located not more than 12 inches below the bottom of the floor joists.

**B.** The openings shall be distributed approximately equally and located to provide cross ventilation, for example, by locating the opening along the length of at least two opposite sides of the building.

**C.** The openings shall be the larger of:

**1.** Openings of not less than 1.5 square feet for each 25 linear feet or fraction of exterior wall; or

**2.** Openings shall be equal to 1 percent of underfloor area.

**D.** The openings may be covered with corrosion-resistant wire mesh with mesh openings of greater than 3 inch and less than 2 inch in dimension.

**91.7104.3.3. Buildings with Natural Ventilation.** A building with natural ventilation is a building constructed with the following:

**A.** The Unobstructed Openings shall exchange outside air.

**B.** The size of the Unobstructed Opening shall be the larger of:

**1** Opening equal to at least 25 percent of the total perimeter wall area of the lowest level of the building, or

**2** Opening equal to at least 25 percent of the floor area of the lowest level of the building.

**C.** The Unobstructed Openings shall be evenly distributed and located within the upper portion of at least two opposite exterior walls of the lowest level of the building.

Buildings with natural ventilation that are constructed as described above, shall have the utilities constructed with Trench Dams and Cable or Conduit Seal Fittings. If there is an enclosed room or space less than 150 square feet within the building, then the enclosed room or space shall be constructed with vent openings that comply with the requirements of Section 91.7104.3.4.

**91.7104.3.4. Enclosed Room or Space within Building.** Individual enclosed rooms or enclosed spaces with floor area less than 2,000 square feet may be exempt from providing the Active System as required by Table 71, provided the vent openings comply with all of the following:

**1** Vent openings are Unobstructed Openings, except screens made with at least 3 inch mesh or wind driven turbines on the roof shall be permitted.

**2** The aggregate size of vent openings shall be the larger of either five percent of the total floor area of the room or the area of enclosed space, or ten percent of the area of walls on the perimeter of the room or enclosed space.

**3** The vent openings shall be located to prevent the accumulation of methane gases within the room or enclosed space.

**4** The top of the vent opening shall be located not more than 12 inches below roof joists or ceiling joists if located in a wall of a building.

**5** The vent openings shall be located on either two opposite walls or two adjacent walls of the room or enclosed space if located in a wall of a building.

**6** The vent openings shall be located no more than 50 feet from any point within the room or enclosed space.

**7** When using wind driven turbine, the area of the vent opening shall be calculated by the area of the opening at the attachment of the wind driven turbine at the roof.

**8** When the vent opening is located in a wall of an adjoining room, then the adjoining room shall be constructed of either an Active System, or have Natural Ventilation as described in Section 91.7104.3.3.

**91.7104.3.5. Single Family Dwelling.** Single Family Dwellings and buildings accessory to single family dwellings shall comply with all the Methane Mitigation requirements of Table 71, except that the following mitigation system may be substituted:

**A. Pressure Sensors below Impervious Membrane may be installed in lieu of** Gas Detection System when Pressure Sensors below Impervious Membrane is not required; or

**B.** Single Station Gas Detectors with battery back-up may be installed in lieu of Alarm System and Gas Detection System; or

**C.** 6 mil thick Visquene may be used in lieu of Impervious Membrane, when the Site Design Levels are I or II; or

**D.** Additional Vent Risers or Mechanical Ventilation may be omitted for buildings with width less than 50 feet and footprint less than 6,000 square feet in area; or

**E.** Vent Risers may be substituted in lieu of Mechanical Extraction System, provided the Vent Risers are designed at a rate twice that established by the Methane Mitigation Standards.

**91.7104.3.6. Buildings Located in the Methane Buffer Zone.** A building, located entirely or partially in the Methane Buffer Zone, shall be designed to the requirements of the Methane Buffer Zone. Buildings located in the Methane Buffer Zone shall not be required to provide any methane mitigation system, if the Design Methane Pressure is less than or equal to two inches of water pressure and is either of the following:

**A.** Areas which qualify as Site Design Level I or II; or

**B.** Areas which qualify as Site Design Level III and the utilities are installed with Trench Dams and Cable or Conduit Seal Fitting.

**91.7104.3.7. De-watering System.** A De-watering system is not required for either of the following:

**A.** If during the site testing, the groundwater level is deeper than 10 feet below the Perforated Horizontal Pipes, or

**B.** If the soil investigation or analysis, as approved by the Department, reveals the groundwater level is more than 12 inches below the bottom of the Perforated Horizontal Pipes.

**91.7104.3.8. Buildings Located in the First Phase Playa Vista Project.** The First Phase Playa Vista project, as approved by the City on September 21, 1993 and December 8, 1995, shall comply with the methane mitigation program as required by the Department pursuant to the Methane Prevention, Detection and Monitoring Program approved by the Department on January 31, 2001, in lieu of the requirements of this division.

**91.7104.4. Paved Areas.** Paved areas that are over 5,000 square feet in area and within 15 feet of the exterior wall of a commercial, industrial, institutional or residential building, shall be vented in accordance with the Methane Mitigation Standards.

**EXCEPTION**: Paved areas located in the Methane Buffer Zone and which qualify for Site Design Levels I, II or III.

**SEC. 91.7105. EXISTING BUILDINGS.**

Additions, alterations, repairs, changes of use or changes of occupancy to existing buildings shall comply with the methane mitigation requirements of Sections 91.7104.1 and 91.7104.2, when required by Divisions 34, 81 or 82 of this Code.

Approved methane mitigation systems in existing buildings shall be maintained in accordance with Section 91.7106.

**SEC. 91.7106. TESTING, MAINTENANCE AND SERVICE OF GAS- DETECTION AND MECHANICAL VENTILATION SYSTEMS.**

All gas detection and mechanical ventilation systems shall be maintained and serviced in proper working condition and meet all requirements of the Electrical and Mechanical Code. The testing, maintenance and service procedure for each gas detection and mechanical ventilation systems shall be performed in accordance with the manufacturers current written instructions and the following:

**A. Fire Department.** The manufacturer=s instructions shall be approved by the Fire Department. Testing and servicing of each system shall be performed by a person certified by the Fire Department.

**B. Notification Placard.** A permanent notification placard shall be posted and maintained at the front entrance of a building that is constructed with Impervious Membrane, except in residential buildings. The placard shall indicate the presence of the Impervious Membrane.

**SEC. 91.7107. EMERGENCY PROCEDURES.**

With the exception of single-family dwellings, all buildings required by this division to have a gas-detection system or sub-slab vent system shall, subject to Fire Department approval, have established emergency procedures that include, but are not limited to, the following:

**A.** Assignment of a responsible person as safety director to work with the Fire Department in the establishment, implementation and maintenance of an emergency plan.

**B.** Conspicuous posting of the Fire Department=s telephone number in areas designated by the Fire Department.

**C.** Conspicuous posting of emergency plan procedures approved by the Fire Department.

**SEC. 91.7108. APPLICATION OF METHANE SEEPAGE REGULATIONS TO LOCATIONS OR AREAS OUTSIDE THE METHANE ZONE AND METHANE BUFFER ZONE BOUNDARIES.**

Upon a determination by the Department of Building and Safety that a hazard may exist from methane intrusion at a geographical location or in an area outside the boundaries established in Section 91.7103 of this Code, the Department of Building and Safety and the Fire Department may enforce any or all of the requirements of Division 71 of this Code as required to preclude potential fire or explosion from methane concentration.

**SEC. 91.7109. ADDITIONAL REMEDIAL MEASURES.**

**91.7109.1. General Remedial Measures.** In the event the concentration of methane gas in any building located in a Methane Zone or Methane Buffer Zone reaches or exceeds 25 percent of the minimum concentration of gas that will form an ignitable mixture with air at ambient temperature and pressure, the owner shall hire an engineer to investigate, recommend and implement mitigating measures. These measures shall be subject to approval of this Department and the Fire Department.

**91.7109.2. Abandoned Oil Well.** Any abandoned oil well encountered during construction shall be evaluated by the Fire Department and may be required to be re-abandoned in accordance with applicable rules and regulations of the Division of Oil, Gas and Geothermal Resources of the State of California. Buildings shall comply with these provisions and the requirements of Section 91.6105 of this Code, whichever is more restrictive.

## TABLE 71. MINIMUM METHANE MITIGATION REQUIREMENTS.

| Site Design Level | | | LEVEL I | | LEVEL II | | LEVEL III | | LEVEL IV | | LEVEL V |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Design Methane Concentration (ppmv) | | | 0-100 | | 101-1,000 | | 1,001-5,000 | | 5,001-12,500 | | >12,500 |
| Design Methane Pressure (inches of water pressure) | | | #2 | >2 | #2 | >2 | #2 | >2 | #2 | >2 | All Pressures |
| PASSIVE SYSTEM | De-watering System 1 | | X | X | X | X | X | X | X | X | X |
| PASSIVE SYSTEM | Sub-Slab Vent System | Perforated Horizontal Pipes | X | X | X | X | X | X | X | X | X |
| PASSIVE SYSTEM | Sub-Slab Vent System | Gravel Blanket Thickness Under Impervious Membrane | 2" | 2" | 2" | 3" | 2" | 3" | 2" | 4" | 4" |
| PASSIVE SYSTEM | Sub-Slab Vent System | Gravel Thickness Surrounding Perforated Horizontal Pipes | 2" | 2" | 2" | 3" | 2" | 3" | 2" | 4" | 4" |
| PASSIVE SYSTEM | Sub-Slab Vent System | Vent Risers | X | X | X | X | X | X | X | X | X |
| PASSIVE SYSTEM | Impervious Membrane | | X | X | X | X | X | X | X | X | X |
| ACTIVE SYSTEM | Sub-SlabSystem | Pressure Sensors Below Impervious Membrane | | | | | | | | X | X |
| ACTIVE SYSTEM | Sub-SlabSystem | Mechanical Extraction System 2 | | | | | | | | X | X |
| ACTIVE SYSTEM | Lowest OccupiedSpace System | Gas Detection System 3 | | X | | X | X | X | X | X | X |
| ACTIVE SYSTEM | Lowest OccupiedSpace System | Mechanical Ventilation 3, 4, 5 | | X | | X | X | X | X | X | X |
| ACTIVE SYSTEM | Lowest OccupiedSpace System | Alarm System | | X | | X | X | X | X | X | X |
| ACTIVE SYSTEM | Control Panel | | | X | | X | X | X | X | X | X |
| MISC. SYSTEM | Trench Dam | | X | X | X | X | X | X | X | X | X |
| MISC. SYSTEM | Conduit or Cable Seal Fitting | | X | X | X | X | X | X | X | X | X |
| MISC. SYSTEM | Additional Vent Risers6 | | | | | | | | | | X |

X = Indicates a Required Mitigation Component

1. See Section 91.7104.3.7 for exception.
2. The Mechanical Extraction System shall be capable of providing an equivalent of a complete change of air every 20 minutes of the total volume of the Gravel Blanket.
3. See Section 91.7104.3.1 for Narrow Buildings.
4. The Mechanical Ventilation systems shall be capable of providing an equivalent of one complete change of the lowest occupied space air every 15 minutes.
5. Vent opening complying with Section 91.7104.3.4 may be used in lieu of mechanical ventilation.
6. The total quantity of installed Vent Risers shall be increased to double the rate for the Passive System.

Sec. 3. The City Clerk shall certify to the passage of this ordinance and have it published in accordance with Council policy, either in a daily newspaper circulated in the City of Los Angeles or by posting for ten days in three public places in the City of Los Angeles: one copy on the bulletin board located in the Main Street lobby to the City Hall; one copy on the bulletin board located at the ground level at the Los Angeles Street entrance to the Los Angeles Police Department; and one copy on the bulletin board located at the Temple Street entrance to the Los Angeles County Hall of Records.

I hereby certify that this ordinance was passed by the Council of the City of Los Angeles, at its meeting of February 12, 2004.

J. MICHAEL CAREY, City Clerk
By Maria Kostrencich, Deputy
Approved February 12, 2004
JAMES K. HAHN, Mayor
Approved as to Form and Legality
January 8, 2004
Rockard J. Delgadillo, City Attorney
By Sharon Siedorf Cardenas
Assistant City Attorney
C.F. 01-1305

***EFFECTIVE DATE: 3-29-04***

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# Appendix B

**INFORMATION BULLETIN / PUBLIC - BUILDING CODE**
**REFERENCE NO.: LABC Chapt. 71** Effective: 11-30-04
**DOCUMENT NO. P/BC 2004-102** Revised:
Previously Issued As: None

## METHANE HAZARD MITIGATION STANDARD PLAN: SIMPLIFIED METHOD FOR SMALL ADDITIONS

## I. PURPOSE

This Information Bulletin describes three simplified methods for complying with the requirements of Division 71of the Los Angeles Municipal Code (LAMC).

- Method A - Buildings with Raised Floors - LAMC Section 91.7104.3.2,
- Method B - Buildings with Natural Ventilation - LAMC Section 91.7104.3.3, and
- Method C - Small On-Ground-Level Additions - LAMC Section 91.7104.2

Methods A and B are exceptions that are specifically allowed in the LAMC. However, Method C requires a special approval by the Superintendent of Building. This Information Bulletin should be attached to the plans to show the method of compliance when obtaining a building permit.

## II. SIMPLIFIED METHODS

Indicate which method is being used by placing a check ( T ) in front of the selected method. Combinations of the following methods are allowed only when approved under Modification of Building Ordinance by the Superintendent of Building. All components listed for each method shall be installed.

♦ **Method A - Additions with Raised Floor Construction**

1. All plumbing pipes, and electrical and communication wiring conduits installed below ground shall be placed in trenches sealed with Trench Dams, as shown in Detail 8 of this bulletin.
2. A clear space of 18 inches shall be maintained between the bottom of the floor joists and earth.
3. A clear space of 12 inches shall be maintained between the bottom of the floor girders and earth.
4. The top of openings for underfloor area or crawl space ventilation shall be located less than 6 inches below the bottom of the floor. These openings shall be sized to be the larger of:
   a. 1.5 square feet for each 25 linear feet of exterior wall, or
   b. 1% of the underfloor area.
5. Openings shall be evenly distributed along the length of at least two opposite sides of the building joists in order to provide cross ventilation.
6. Openings shall be covered with corrosion-resistant wire mesh with mesh openings not less than 1/4 inch nor greater than ½ inch in dimension.

- **Method B - Additions with No Walls or Mostly Open (carports, gazebos, barns, etc.)**
  1. All plumbing pipes, and electrical and communication wiring conduits installed below ground, shall be placed in trenches sealed with Trench Dams as shown in Detail 8 of this bulletin.
  2. At least two sides of the structure shall be completely open or if walls are provided, there shall be evenly spaced openings along the exterior walls as follows:
     - On two or more exterior sides to provide cross-ventilation.
     - Less than 50 feet from any point within the addition.
     - Clear of obstructions except for screens of wire mesh.
  3. The total area of openings shall be the larger of:
     - 25% of total floor area of the ground floor addition, or
     - 25% of the total perimeter wall area of the ground floor addition.

- **Method C - Additions with Slab on Grade**

  Where specifically approved by Modification of Building Ordinance by the Superintendent of Building as an alternate for use in a building, all of the following components shall be installed using the details of this Information Bulletin:
  1. 6 mil. thick **Visquene** placed below the floor slab,
  2. 2 inch thick **Gravel** layer placed below the Visquene barrier,
  3. One 4-inch diameter **Perforated Horizontal Vent Pipe** (slotted or perforated PVC pipe) placed below the **Gravel** layer,
  4. Two 2-inch diameter **Vent Risers** placed vertically in the building walls and connected to the two ends of the **Perforated Horizontal Vent Pipe**, and
  5. **Conduit and Cable Seal Fittings** installed in electrical conduits penetrating the floor of the addition.

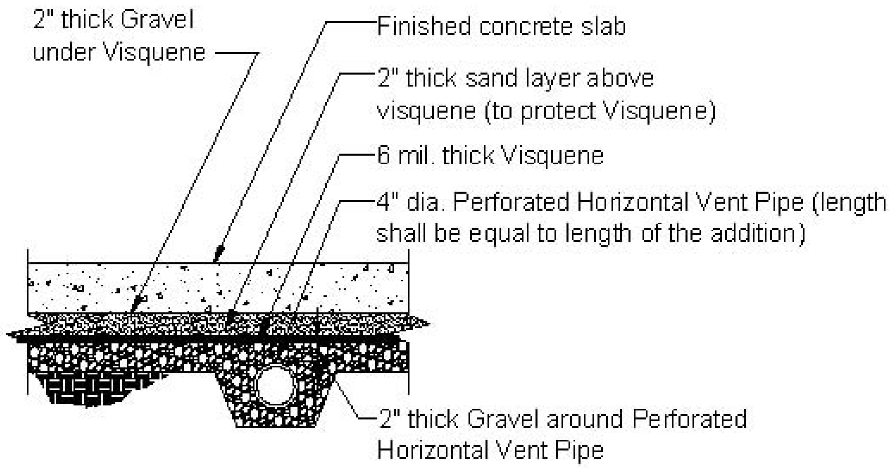
## III. MAINTENANCE OF MITIGATION SYSTEMS

All components of the systems described in either of the methods shall be maintained and serviced to be in proper working condition.

## IV. INSPECTION REQUIREMENTS

Inspection by a City of Los Angeles Department of Building and Safety inspector shall be conducted prior to the covering of any component required by the Methane Mitigation System outlined in this Information Bulletin.

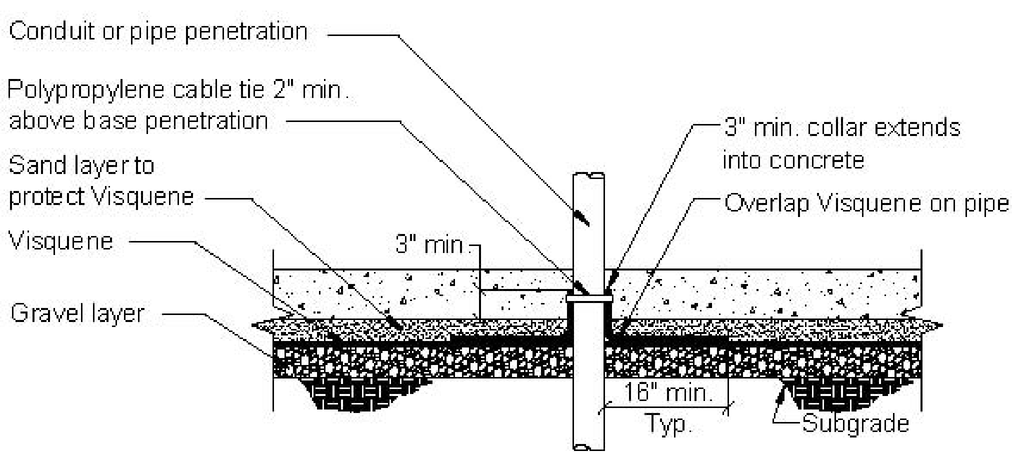
## Detail 1 - Typical Cross Section



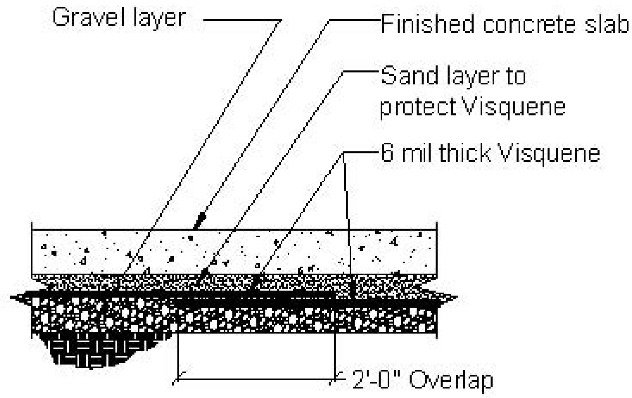

Note:

1. If groundwater is found during footing excavation, then special approval from the Department of Building and Safety is required for dewatering.
2. Gravel shall be clean crushed rock with maximium particle size of 3/8" and less than 10% passing sieve No. 8.
3. Sand shall be clean sand with less than 10% passing Sieve No. 100.

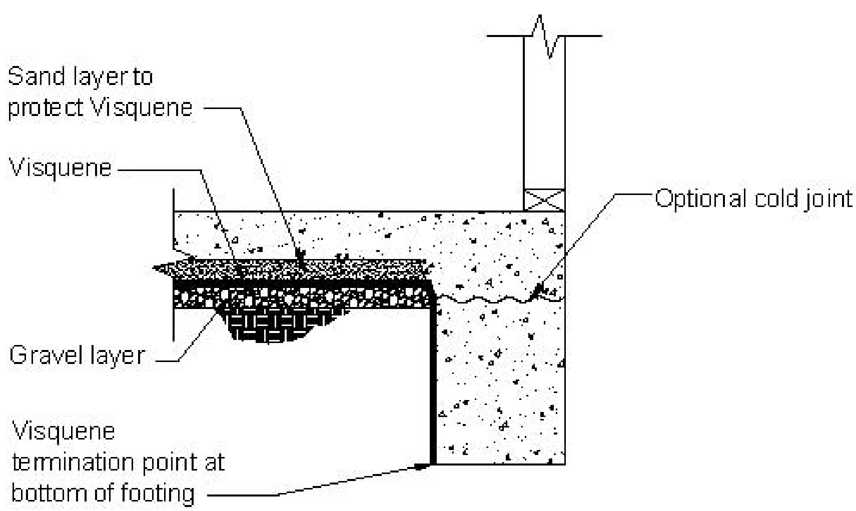
## Detail 2 - Visquene Penetration



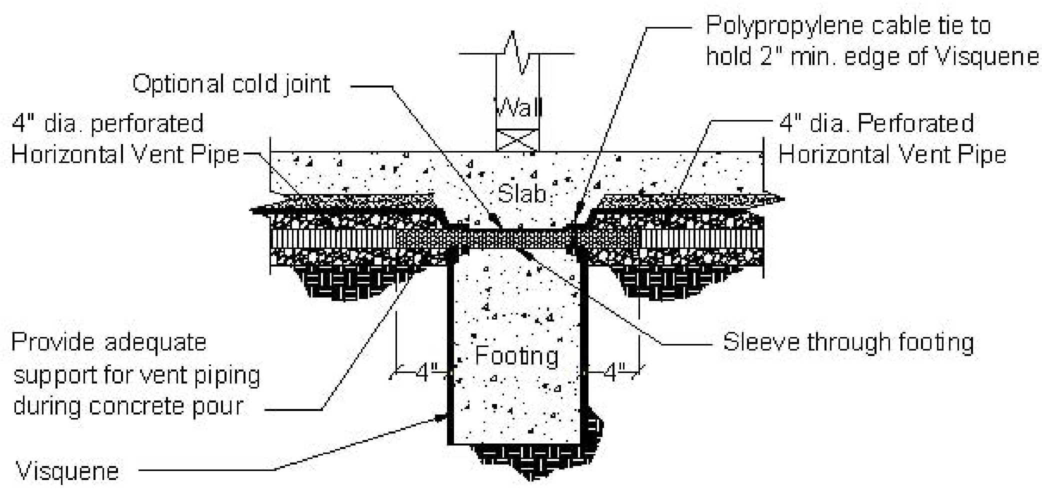
## Detail 3 - Visquene Overlap




## Detail 4 - Visquene Termination at Exterior Footing

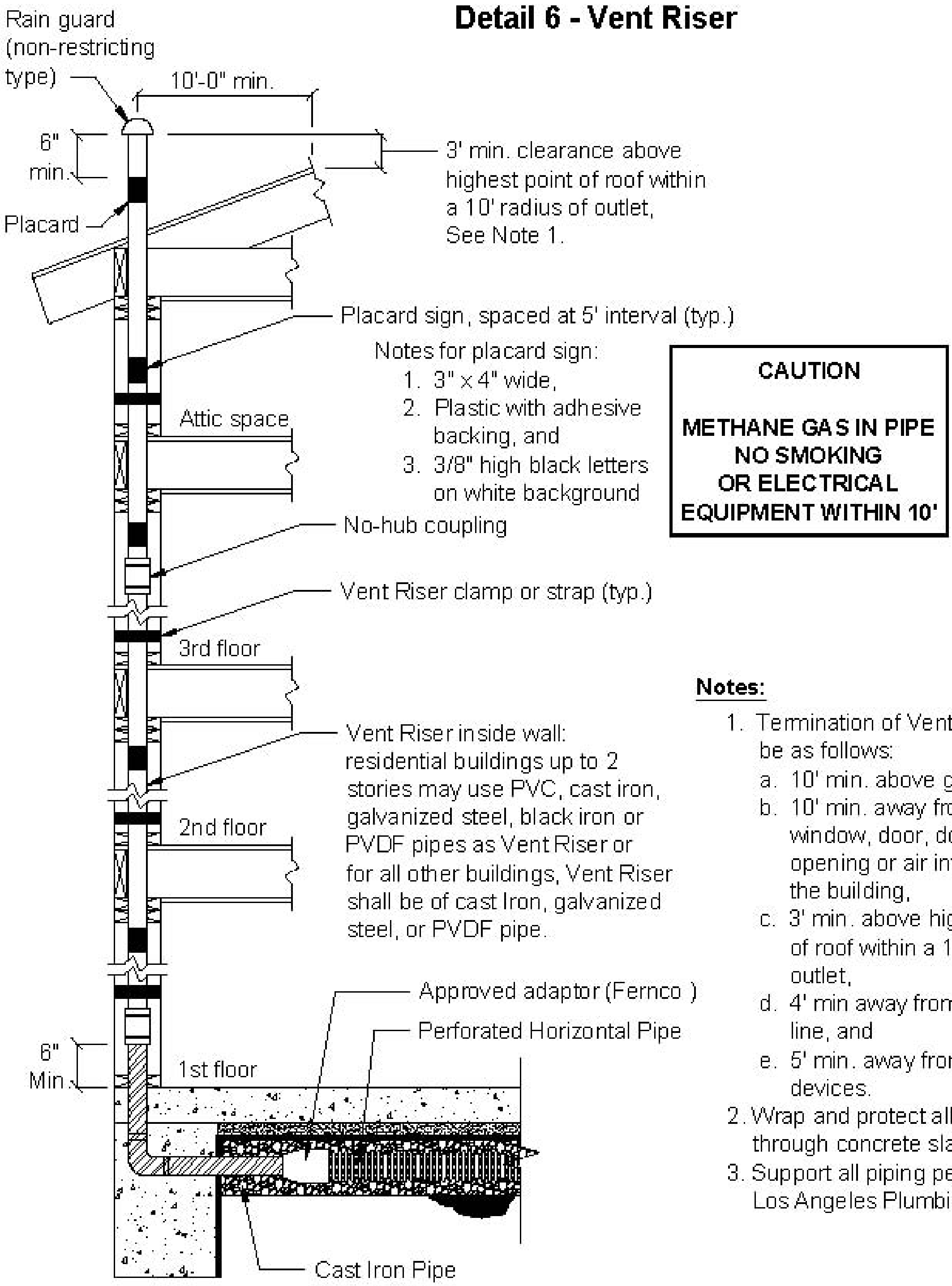


## Detail 5 - Perforated Horizontal Vent Pipe and Visquene at Interior Footing



**P/BC 2004-102**

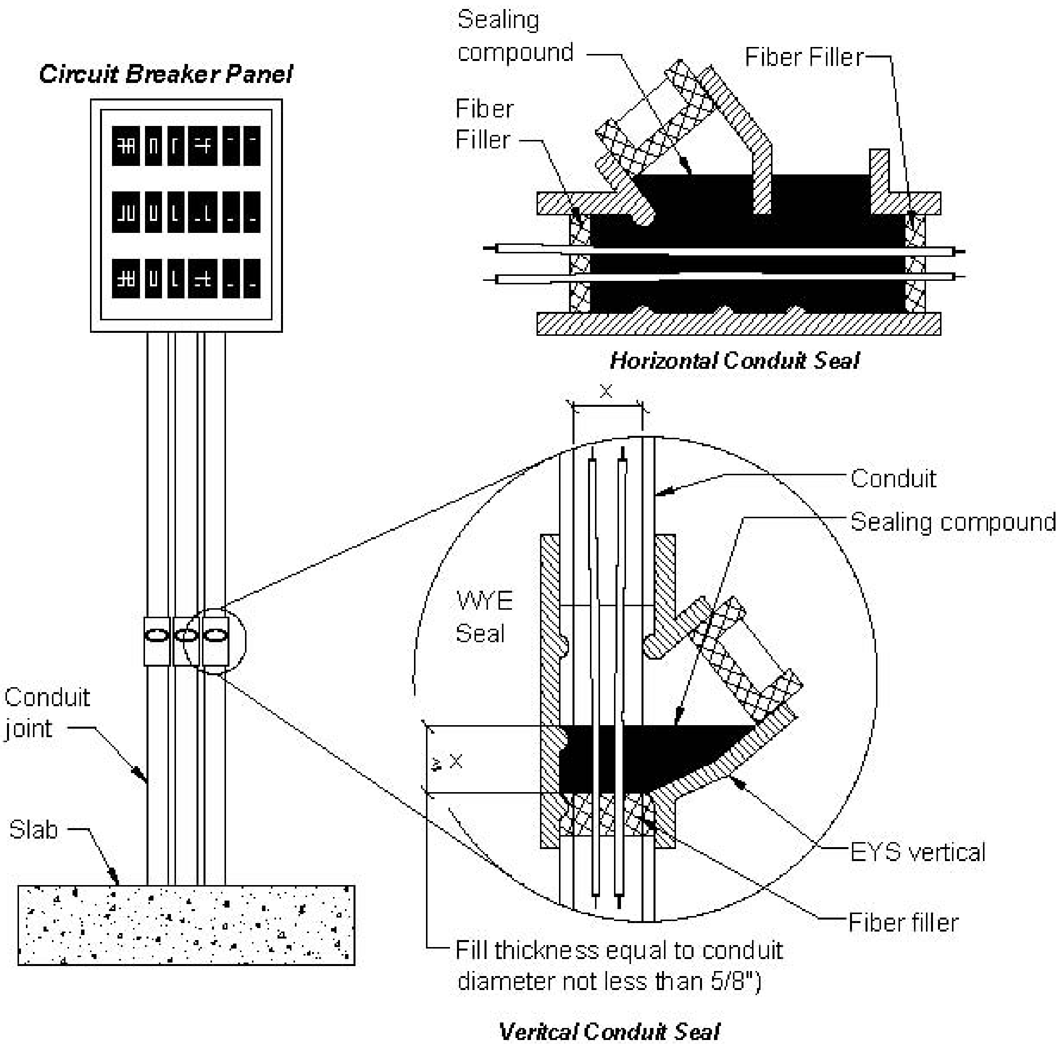
# Detail 6 - Vent Riser




**Notes:**

1. Termination of Vent Riser shall be as follows:
   a. 10' min. above grade,
   b. 10' min. away from any window, door, door hatch, opening or air intake into the building,
   c. 3' min. above highest point of roof within a 10' radius of outlet,
   d. 4' min away from property line, and
   e. 5' min. away from eletrical devices.
2. Wrap and protect all piping through concrete slab or floor.
3. Support all piping per Table 3-2 of Los Angeles Plumbing Code.

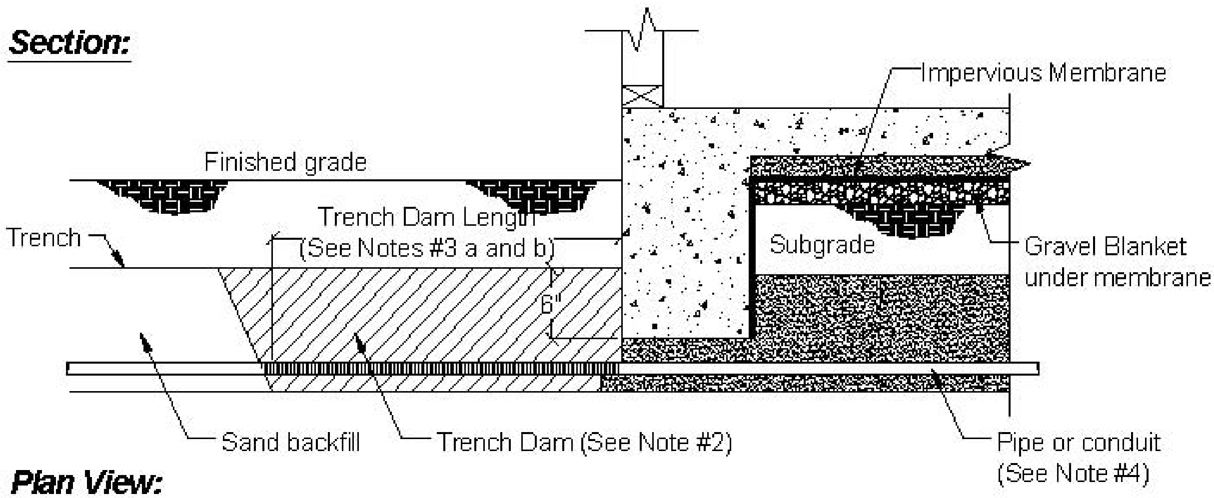
## Detail 7 - Conduit Seal



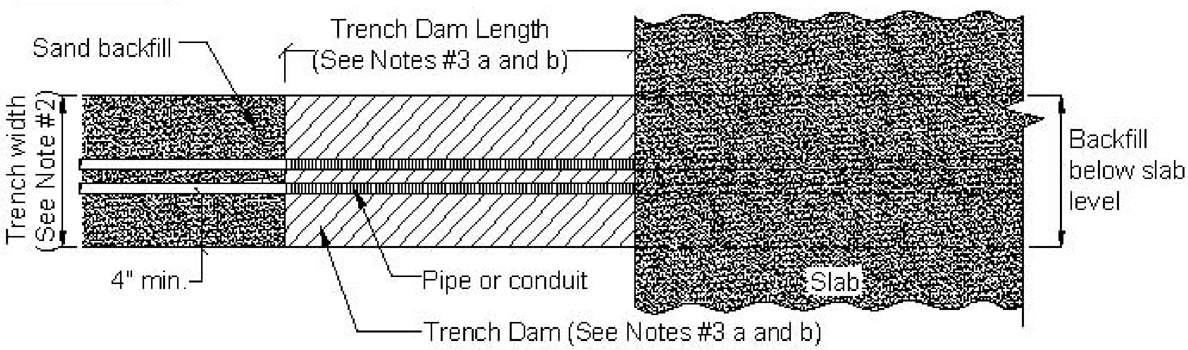
**P/BC 2004-102**

# Detail 8 - Trench Dam

**Section:**




**Plan View:**




**Notes: Trench Dams**

1. All Trench Dams shall be installed in trenches containing piping and conduit that connects directly from the utility lines in the street.
2. The width of a Trench Dam shall be one half the length.
3. Trench Dams shall be constructed of one of the following:
   a. Bentonite Cement Slurry three feet long: A mixture of 4% Type II Cement, and 2% Powdered Bentonite.
   b. Compacted Native Soils Backfill five feet long: Native soils shall be compacted at least 90% relative compaction in accordance with ASTM D-1557 Testing Procedures.
   c. Concrete mixes other than Bentonite Cement Slurry may be used provided conduit or piping is wrapped with High Density PVC Foam Tape, Closed Cells, Adhesive Backed, 1/4" thick by ½" wide shall be applied to clear surface with ends butted together at most visible locations in Trench Dam.
4. Piping and conduit shall be protected from corrosion and structural settlement as follows:
   a. Tape shall be applied on conduit and piping encased in cement slurry or concrete.
   b. Tape shall be PS-37-90, Black Plastic PVC or PE Pressure-Sensitive Corrosion Preventive Tape.

# Appendix C

Huntington Beach Municipal Code 17.04.010--17.04.070

## Chapter 17.04

## BUILDING CODE

(375-8/34, 530-5/48, 592-12/52, 869-9/61, 1064-7/64,1139-5/65, 1331-7/67,1626-2/71, 1935-11/74, 2027-1/76, 2431-7/80, 2747-2/85, 2787-9/85, 2875-11/86, 2976-12/88, Urg. Ord. 3006-6/89, 3004-8/89, 3022-12/89, 3147-7/92, 3260-11/94, 3261-11/94, 3305-12/95, 3422-7/99, 3573-10/02)

**Sections:**



**17.04.010 Title.** This chapter shall be known as the Huntington Beach Building Code, may be cited as such, and will be referred to herein as the Building Code. (1935-11/74, 2027-1/76, 2431-7/80, 2747-2/85, 3422-7/99)

**17.04.020 Adoption.** There is hereby adopted by the City Council by reference that certain code known as the 2001 California Building Code, and the whole thereof, including appendices thereto except as hereinafter provided. Such code, and amendments thereto, are hereby adopted and incorporated, pursuant to California Government Code §50022.2 et seq., and Health and Safety Code § 18941.5, as fully as though set forth at length herein, for the purpose of regulating the erection, construction, enlargement, alteration, repair, moving, removal, conversion, demolition, occupancy, equipment, use, height, area, and maintenance of buildings or structures in the City of Huntington Beach, and repealing all ordinances and parts of ordinances in conflict herewith. From the date on which this chapter takes effect the provisions of such code, together with amendments thereto shall be controlling within the corporate limits of the City of Huntington Beach. (375-8/34, 530-5/48, 592-12/52, 869-9/61, 1064-7/64, 1139-5/65, 1331-7/67, 1626-2/71, 2027-1/76, 2431-7/80, 2747-2/85, 2976-12/88, 3022-12/89, 3147-7/92, 3305-12/95, 3422-7/99, 3573-10/02)

**17.04.030** Chapter 1 of the Building Code is hereby deleted. (2431-7/80, 2747-2/85, 3305-12/95, 3422-7/99)

**17.04.060 § 1900.4.4 amended--Minimum Slab Thickness.** § 1900.4.4 of the Building Code is amended to read as follows: (3305-12/95, 3422-7/99)

§ 1900.4.4. All concrete floor slabs on grade shall have a minimum net thickness of 3 1/2 inches, and shall be provided with minimum reinforcing equal to 6 x 6-W1.4 x W1.4 welded fabric. When such slabs are to be covered with carpet or any floor covering they shall be separated from the ground by two (2) inches of clean sand over an approved vapor barrier. (2027-1/76, 2431-7/80, 2747-2/85, 2976-12/88, 3305-12/95, 3422-7/99)

**17.04.070 § 904.2 amended--Automatic Fire-Extinguishing Systems.** § 904.2 of the Building Code is modified by adding the following to subsection 904.2.1 to read as follows: (3022-12/89, 3305-12/95, 3422-7/99)

§ 904.2.1 For amended sprinkler requirements, see Huntington Beach Municipal Code, Chapter 17.56 of this code. (2027-1/76, 2431-7/80, 2747-2/85, 3022-12/89, 3305-12/95, 3422-7/99)

**17.04.080 Chapter 36 added--Building security.** The Building Code is hereby amended by adding thereto new Chapter 36 entitled, "Building Security," to read as follows: (3022-12/89, 3305-12/95, 3422-7/99)

§ 3601. Purpose. The purpose of this chapter is to establish minimum standards of construction for protection against unlawful entry. (3305-12/95)

§ 3602. Alternative security provisions. When approved by the building official, site security systems may be provided in lieu of the specific security provisions of section 3608, 'Garages--Multiple dwellings.' (3022-12/89, 3305-12/95, 3422-7/99)

§ 3603. Definitions. For the purpose of this chapter, certain terms used herein are defined as follows: (3305-12/95, 3422-7/99)

'Cylinder guard' means a hardened ring surrounding the exposed portion of the lock cylinder or other device which is so fastened as to protect the cylinder from wrenching, prying, cutting or pulling by attack tools.

'Deadlocking latch' means a latch in which the latch bolt is positively held in the projected position by a guard bolt, plunger or auxiliary mechanism.

'Dead bolt' means a bolt which has no automatic spring action and which is operated by a key cylinder, thumb turn, or level, and is positively held fast when in the projected position.

'Latch' means a device for automatically holding a door shut after being closed.

'Light' means any glazed opening whether glazed with glass, plastic, metal, wood or composition sheets or panels, or similar materials, and shall include windows, skylights, view ports or view panels and similar openings.

§ 3604. Entry vision. All main or front entry doors to R occupancies shall be arranged so that the occupant has a view of the area immediately outside without opening the door. Such view may be provided by a door viewer or view port or by window or other opening located and constructed as required by this chapter. Such area shall be provided with a light. (3305-12/95, 3422-7/99)

§ 3605. Doors. (3305-12/95, 3422-7/99)

(a) General. A door forming a part of the enclosure of a dwelling unit or of an area of a building occupied by one tenant shall be constructed, installed, and secured as set forth in this section.

(b) Swinging doors.

(1) Swinging wooden doors which can be opened from the inside without using a key shall be of solid core construction. Lights in doors shall be as set forth in this chapter. (3022-12/89)

(2) A single swinging door, the active leaf of a pair of doors, and the bottom leaf of Dutch doors shall be equipped with a dead bolt and deadlocking latch. The dead bolt and latch may be activated by one lock or by individual locks. Dead bolts shall contain hardened inserts, or equivalent, designed to repel cutting tool attack. The lock or locks shall be key.operated from the exterior side of the door and engaged or disengaged from the interior side of the door by a device which requires no key, special knowledge or effort.

(3) A straight dead bolt shall have a minimum throw of one (1) inch and the embedment shall be not less than five-eighths (5/8) inch into the holding device receiving the projected bolt. All dead bolts of locks which automatically activate two (2) or more dead bolts shall embed at least one-half (1/2) inch but need not exceed three-fourths (3/4) inch into the holding devices receiving the projected bolts. (3022-12/89)

(4) A deadlocking latch shall be provided with a bolt projecting not less than five-eighths (5/8) inches from the edge of the door in which it is installed.

(5) The inactive leaf of a pair of doors and the upper leaf of Dutch doors shall be equipped with a dead bolt or dead bolts as set forth in subsection (b)(2) above.

**EXCEPTIONS**:

(1) The bolt or bolts need not be key operated but shall not be otherwise activated, from the exterior side of the door.

(2) The bolt or bolts may be engaged or disengaged automatically with the dead bolt or by another device on the active leaf or lower leaf.

(3) Manually-operated hardened bolts at the top and bottom of the leaf and which embed a minimum of one-half (1/2) inch into the device receiving the projected bolt may be used when not prohibited by the Building Code or other laws and regulations.

(6) Doorstops on wooden jambs for in-swinging doors shall be of one piece construction with the jamb or joined by a rabbet.

(7) Nonremovable pins shall be used in pin-type hinges which are accessible from the outside when the door is closed.

(8) Cylinder guards shall be installed on all mortise or rim-type cylinder locks installed in doors whenever the cylinder projects beyond the face of the door or when otherwise accessible to gripping tools.

(9) Unframed glass doors shall be of fully tempered glass not less than one-half (1/2) inch thick.

(10) Narrow-framed glass doors shall be of fully tempered glass not less than one-quarter (1/4) inch thick.

(c) Sliding glass doors. Sliding glass doors shall be equipped with locking devices. Cylinder guards shall be installed on all mortise or rim-type cylinder locks installed in doors whenever the cylinder projects beyond the face of the door or is otherwise accessible to gripping tools. (3305-12/95)

<u>§ 3606. Windows, or other openings</u>. (3422-7/99, 3573-10/02)

(a) <u>General</u>. Windows, or other similar openings shall be constructed, installed and secured as set forth in this section. (2976-12/88, 3022-12/89, 3422-7/99, 3573-10/02)

(b) <u>Materials</u>. Only fully-tempered glass or approved metal bars, screens, or grills shall be used for any opening in which glass is utilized which is located within forty (40) inches of the locking device on a door. (3305-12/95)

(c) <u>Locking devices</u>**.** All windows or other openings which are designed to be opened shall be provided with locking devices. (3305-12/95, 3573-10/02)

<u>§ 3608. Garages--Multiple dwellings</u>. Whenever a development includes three (3) or more dwelling units, all covered parking required by other provisions of the Huntington Beach Ordinance Code shall be provided by fully-enclosed garages. Garage space for each tenant shall be separated by partitions of three-eighths (3/8) inch plywood or any approved equivalent with studs set not more than twenty-four (24) inches apart on one side. Doors and windows in such garages shall be constructed, equipped and secured as required by this chapter. (2027-1/76, 2431-7/80, 2456-11/80, 2747-2/85, 2787-9/85, 3022-12/89, 3305-12/95, 3422-7/99)

**17.04.085 Methane District Regulations.** The Building Code is hereby amended by adding thereto new Chapter 55 entitled "Methane District Regulations" to read as follows: (3004-8/89, 3022-12/89, 3422-7/99)

§ 5501. Purpose. This Division sets forth the minimum requirements of the City of Huntington Beach for new building construction in the defined methane overlay districts. It is also the purpose of this chapter to reduce the hazards presented from accumulations of methane gas by requiring the appropriate testing and mitigation measures for all new buildings in the methane overlay districts.

§ 5502. Definitions. For the purposes of this division, the following definitions shall also be applied.

A. Flammable Gas shall mean any gaseous substance capable of sustaining combustion or explosion.

B. Gas Detection System shall mean one or more electrical devices capable of continuous monitoring for the presence of flammable gasses and containing an audible alarm capable of alerting occupants that a hazardous atmosphere exists. A part of the system shall be subject to building the system and all devices which are department and fire department approved.

C. Methane Gas shall mean the hydrocarbon substance commonly known as "natural gas," chemical formula $CH_4$. For the purposes of definition in this chapter, natural gas from the distribution system of a utility company is exempted and excluded from the scope of the application of the provisions of this chapter.

D. Methane Gas Overlay District shall mean those districts within the City of Huntington Beach as defined in Section 5503.

E. Qualified Engineer shall mean a civil engineer currently registered in the State of California and possessing experience in the design of subsurface gas control systems.

F. Vent System shall mean a system or device which gathers or collects flammable gasses and releases these gasses in a specified manner and location.

§ 5503. Overlay Districts. Boundaries of the districts set forth herein are measured from centerline to centerline of indicated streets unless otherwise described, and are graphically depicted by the copy of the map designated "Methane Overlay Districts," which is on file with the Fire Department. (3422–7/99)

The Methane District boundaries are as follows. Note that the directions of north, south, east, west, and similar directions are general in nature only.

District One: Saybrook Lane south from Edinger Avenue to Davenport Drive to Algonquin Street, south on Algonquin Street to Warner Avenue, east on Warner Avenue to Bolsa Chica Street, north on Bolsa Chica Street to Edinger Avenue, west on Edinger Avenue to Saybrook Lane.

District Two: All land on both sides of Pacific Coast Highway northwest from the City Boundary at the Santa Ana River to the City Boundary at the Bolsa Chica Bluffs, then following the City Boundary northeast to Edwards Street, Edwards Street north to Slater Avenue, Slater Avenue east to Gothard Street, Gothard Street south to Ellis Avenue, Ellis Avenue east to Newland Street, Newland Street south to Adams Avenue, Adams Avenue east to the City Boundary at the Santa Ana River, City Boundary south along the Santa Ana River to Pacific Coast Highway.

§ 5504. Plan Required. All proposed subdivisions, divisions of land, developments of property, and new buildings within the methane overlay districts shall be reviewed by the Fire Department. The Fire Chief may require a plan for the testing of site soils for the presence of methane gas. Such plan shall be subject to the approval of the Fire Department, and may include, but shall not be limited to, hammer probes, pneumatically driven probes, and core hole samples with monitoring for the presence of methane gas. The Fire Chief may require other actions as deemed necessary to insure the safety of the development or building site.

§ 5505. Testing Required. Testing for the presence of methane gas shall be required to be carried out in accordance with the approved plan. Results of such testing shall be submitted to the Fire Department for review and analysis.

§ 5506. Mitigation Required. Anomalously high levels of methane gas in the near surface or subsurface soil layers may require mitigation before any grading, development, or building construction is allowed to take place. Such mitigation may include, but is not limited to, the venting of abandoned oil wells, underground gathering and collection systems for gasses, vent systems, and flared vent systems. Other systems, devices, or components may be required as deemed necessary by the Fire Chief in order to insure the safety of the development and buildings.

If the mitigation measure does not reduce the soil concentrations of methane to an acceptable level, or if other contaminants are present in the methane at a level which poses a threat to health and safety, further development may be halted until such time as the site is rendered safe from these hazards.

§ 5507. Isolation Barriers Required. New buildings which fall under the provisions and requirements of this article may require the installation of a continuous, flexible, permanent, and non-permeable barrier, and shall be a type approved by the Fire Department. (3422-7/99)

§ 5508. Access. All methane gas mitigation systems required by this article shall be made accessible to city personnel for the purposes of monitoring, maintenance, and evaluation for effectiveness.

§ 5509. Areas Outside of Established Methane Overlay District Boundaries. Upon the determination of the Fire Department that hazard may exist from methane intrusion at a geographical location or area outside the boundaries established in Section 5503 above, the Fire Department may enforce any or all of the provisions of this article as deemed necessary by the Fire Chief to preclude potential hazards from fire or explosion from methane gas accumulations.

§ 5510. Additional Remedial Measures. If the concentration of flammable gas in any building in the City reaches or exceeds twenty-five percent (25%) of the minimum concentration which form an ignitable mixture with air at ambient temperature and pressure, the owner of such building shall hire a qualified engineer to investigate, recommend, and implement mitigating measures. Such measures shall be subject to the approval of the Fire Department. (3422-7/99)

**17.04.090 Amendments to appendices.** The Building Code is hereby amended by deleting from the appendices Chapter 3-Div. I, III & IV, 4, 9, 10, 11, 12-Div. I & II, 13, 16 -Div. I, II, & III 19, 21, 23, 29, 30, 33, 34- Div. I & II. (2431-7/80, 2747-2/85, 2976-12/88, 3022-12/89, 3147-7/92, 3261-11/94, 3305-12/95, 3422-7/99, 3573-10/02)

**17.04.095 Appendix Chapter 15, § 1516.** Subsection 1516.3.(1) entitled Asphalt Shingles - is hereby amended to not allow more than one (1) overlay of asphalt shingle over the existing roofing system unless structural calculations are submitted to justify the additional weight. (3147-7/92, 3305-12/95, 3422-7/99)

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